GEOLOGICAL SURVEY OF INDIA

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MEMOIRS

OF THE

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OF

INDIA.

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INDIA.

VOL. III.

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UNDER THE DIRECTION OF

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CONTENTS.

LIST OF ILLUSTRATIONS, &c.

MAPS.

PLATES.

DIAGRAMS, &c.

Raniganj Field. Page.

Sub-Himalayan Rocks.

I desire to take this public opportunity of correcting an error, into which I regret much I was led by a mistaken impression which I received in conversation. At page 198, I have stated that Mr. Rupert Jones had identified the Mangali crustaceans as *Estheria minuta*. This was not the fact, as appears more fully in Mr. Jones' own papers, subsequently published.

T. OLDHAM.

ERRATA.

It not unfrequently happens that these Memoirs are unavoidably printed during the absence of the writer, or of myself, from Calcutta, when the needful facilities for correcting the proofs cannot be secured. The reader is requested to make the following corrections :—

Page 14,	line 15	*for*	531	read	53.
32,	,, 17 & 25	,,	Railyádi	,,	Bailyádi.
45,	,, 29	,,	this Report	,,	the Report.
{ 71, 72,	last line, first line }	,,	405	,,	505
75,	last line but one			,,	Black carbonaceous Shales and Ironstones ... 20 *Lower Damúdas.*
86,	line 9	,,	0 0	,,	0 0½.
86,	,, 18	,,	24 5	,,	24 5½.
89,	,, 1	,,	Diguala	,,	Dignala.
92,	,, 24	,,	260	,,	261
95,	,, 9	,,	light	,,	bright.
102,	,, 20	,,	East 10°—20° West	,,	East 10°—20° North.
106,	last line	,,	W. N. W.	,,	W. S. W.
118,	line 3	,,	No	,,	The.
119,	,, 20	,,	Bara	,,	Bora.
133,	,, 1	,,	Rájmahál	,,	Ràniganj.
137,	,, 7	,,	unfossiliferous	,,	fossiliferous.
142,	,, 27, 28, 29	,,	where East occurs	,,	West and *vice versa.*
148,	,, 6 from bottom	,,	latter	,,	later.
157,	,, 16 ,,	,,	proprieters	,,	proprietors.
165,	,, 8 ,,	,,	finer	,,	firmer.
172,	,, 16 ,,	,,	5 to 6 pie	,,	5 to 6 pice.
181,	,, 4 ,,	,,	Gushik	,,	Gushin.

On the map, a small isolated portion of 'Ràniganj' rocks, in the extreme east of the map, close to River Adjai, and between the villages of Samla and Bhonri, has been erroneously *coloured* as Lower Damuda.

Preliminary Notice.

The following Report on the Rániganj coal field, by Mr. W. T. Blanford, is the result of an examination of that important district, made during 1858-60.

When, in 1856, the duties of the Geological Survey in India were systematized and extended, it was determined to confine, so far as possible, the attention of the Geologists attached to the survey to such portions of the country as had been surveyed and mapped, either by the Great Trigonometrical, or by the Revenue, Surveys and of which, consequently, maps existed sufficiently detailed and accurate for the record of the Geological observations. It was hoped, that in this way, the time of those engaged in the Geological examination of the country which had been previously devoted to the preparation of such maps, would be saved. Acting on this principle, this very important and interesting coal field had been passed over, because no maps of it had been published by the Surveys in India. It was well known to myself and to others of the Geological Survey of India, who had, in the progress of their labors, crossed this field, that there were many points of great interest, which called for further elucidation, and several which demanded important corrections, in the Report and Map of Mr. Williams, who had geologically examined this field in 1845-47. But these had all been reserved until the completion of a map of the country by the Revenue Survey. Towards the close, however, of the year 1858, the great demand for increased Railway accommodation from the proprietors of collieries, and the desire to open out this valuable mineral district more fully than had already been the case, led to an enquiry from the Geological Survey, on the part of the Government, for information as to the actual sites of the collieries at work on the field, the value of these, and the best direc-

tion for an extension of the line of Railway adapted to meet the increasing demand for coal, and for its conveyance to market.

The usual working season of 1858-59 had already considerably advanced, when, in compliance with this desire on the part of Government, Messrs. W. Blanford and W. L. Willson, then both engaged in Birbhúm, were requested to take up the examination of this field. It was my object to secure, if practicable, during that season, an examination of the whole of the more important part of this field. And this was to a very great extent accomplished. Early in 1859, I went myself over all the most productive parts of the field, and then reported to the Government on the matters referred specially for my consideration. A large portion of the district, however, was necessarily left unvisited, including all lying south of the River Damúda. The examination of this was resumed in the next working season, 1859-60, by Mr. W. Blanford alone.* He also re-visited all the other parts of the field, and by the close of the working season in May 1860, he had completed the field-work of the entire district. During the monsoon of that year, this Report and the Map were prepared; and in the early part of 1861 the entire field was re-visited by myself, and the Map carefully checked.

This is the first Map which the Geological Survey in India has issued on the larger scale of 1-inch to the mile, on which scale, however, all our field-work is recorded, wherever the maps exist. It would, in this case, have been impossible to have given all the detail which Mr. Blanford has carefully entered on his map, on a smaller, and the importance of the field would fully justify even a larger, scale than this.

This being also the first instance in which the maps of the Geological Survey refer to districts of which no authorized map has yet

* Mr. Mallet, in 1858-59, and Mr. Tween, in 1859-60, both worked with Mr. Blanford, but as these gentlemen were new and untrained assistants, their aid was not of much importance.

been published by the Government Surveys, I have felt myself at liberty, without interfering with such maps, to adopt that system for the transliteration of native names for localities, which is in use by the great Trigonometrical Survey. This is fundamentally the system of Sir William Jones. It is not assumed that the names on this map will in all cases be found correctly spelled, even on that system. There are great, and indeed almost insurmountable difficulties where, as in the case of the Geological Survey, the only knowledge of the names of places can be acquired from the illiterate natives, no two of whom will probably pronounce the name even of their own village in exactly the same way. But still it is hoped that the present will be found an improvement on all former maps of this district, as regards the orthography of the names.

That there is really no great difficulty in arriving at the correct spelling of the names of all places in any part of the country, I have been satisfied long since, and I may give an instance here which will elucidate this. The name, Panchét, which will be found to recur so frequently in the following pages, was found spelled indifferently on previous maps, as follows ; Pachate, Pachet, Panchete, Panchooit, Pachite, Pachit. Even the same word is on one map spelled Pachet when applied to the hill, and Panchooit when applied to the village close by. Mr. Blanford corrected the spelling into Panchit, giving the true sound of the first syllable. But feeling satisfied that for a name so well known there must be some acknowledged and admitted derivation, and therefore some established and correct mode of spelling, I applied for information to Baboo Rajendralalá Mittra, whose profound knowledge of Bengali and Sanscrit is well known, and he at once stated that the name was supposed, by most persons, and among others by the Rajah of the place, to be derived from *Pancha kota*, or five forts—but that in an old Sanscrit book he found it stated to be taken from *Pancha kuta* or five peaks, from the hills adjoining. *In*

either case the correct spelling of the word would undoubtedly be Panchét, the *n* being nasal and only slightly sounded. This spelling has, of course, been adopted. Numerous other cases might be cited, showing how easy it would be to arrive at, and fix, once for all, the true spelling of the ordinary names of places, and how easy it would then be to transliterate these names according to any fixed system. An attempt has been made in the accompanying map to do this uniformly on the system adopted by the Trigonometrical Survey of India, and thus to avoid the confusion of names which arises from the use of two totally different, and in many respects opposing systems, by the two authorized Survey establishments of the country. In the present case, this does not interfere with any official maps, as none such exist, excepting for a small portion of the eastern end of the field.

A few remarks have been added to Mr. Blanford's report, supplementary to the paper already published in the second volume of these Memoirs, on the Geological age of these Indian rocks.

I gladly take this opportunity of offering publicly the best thanks of the Geological Survey to the Proprietors of the several collieries, their Agents in the field, and Secretaries, for the kindly aid which they afforded during the progress of the examination of this field. For a considerable portion of the valuable information detailed herein, the Geological Survey is indebted to them.

T. Oldham.

Calcutta, June 1861.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the Geological Structure and Relations of the RÁNIGANJ COAL FIELD, BENGAL. *By* WILLIAM T. BLANFORD, F. G. S., *Geological Survey of India.*

PART I.

GEOLOGY OF THE RÁNIGANJ FIELD.

CHAPTER I.—*Sketch of previous knowledge of the Geology of the Field.*

LONG after the Geology of other portions of India had attracted the attention of Voysey, Newbold, Franklin, and other observers, and even after considerable progress had been made in classifying the rocks of the central and Southern portions of the Peninsula, the formations of Bengal remained almost completely unnoticed. This appears especially surprising in the case of the district of coal-bearing rocks, known as the Panchét (Pachete), or Burdwan, or Beerbhoom, or Damúda, and now more generally as the Ràniganj, field, since coal was known to occur there so long ago as 1774, and was actually worked in 1777, while in 1830, when only a single most imperfect account of its Geology existed, several collieries of considerable extent were flourishing. Until 1845, when a regular Geological Survey was undertaken, no general account of the formations existed, which had the least

claim to accuracy; and the only notices which had appeared were the following:—

Described by Mr. Jones, 1829.

The earliest mention of the field appears to be in a paper by Mr. Jones, who first opened mines in 1815, at Rániganj itself, though other collieries had previously existed in various places more to the West; one, at Damúlia, being not more than a mile distant. This paper appears in the XVIIIth volume of the *Asiatic Researches*, page 163, and was published in 1829, but was written several years before, about 1817. It is entitled "*Description of the North-West Coal District, stretching along the River Damúda, from the neighborhood of Jeria or Juriagerh, to below Sanampúr**; *in the Pergunnah of Sheargerh, forming a line of about* 65 *miles.*" The accompanying map, however, does not include Juriagerh in the coal formation, which is represented as only extending about two-thirds of that distance. The principal portion of the paper is devoted to an account of the Rániganj seam, and of the various circumstances noted in sinking shafts for the mine. Some peculiar anomalies in the dips, which appear to have considerably puzzled Mr. Jones, were doubtless due, in the *first* place, to the sandstone being false-bedded; and, *secondly*, to the shafts being sunk in the immediate neighborhood of two or three faults. Mr. Jones concluded that the general dip of the beds, which was South-east in the neighborhood of Rániganj, wheeled to the North-east at the shafts, and he speculated upon the probabilities of coal being found at Kutwa on the Húgli, and of its underlying the alluvium of Bengal, which he supposes to be of no great thickness. It is evident that Mr. Jones's explorations were confined to the immediate neighborhood of Rániganj, since otherwise he could scarcely have failed to observe that the dip of the strata at Ránigaj

* This is probably Serampúr, a village on the Damúda, South of Andál, close to which sandstones are seen.

is quite exceptional, a Southerly dip being the prevalent one elsewhere; and it is probable that, in a great measure, he depended upon native information for the accounts of the extension of the field. At any thing like a description of the coal formation there is no attempt in the paper.

Rev. R. Everest, 1831.

In May 1831 appeared a short notice of *Geological Observations made on a Journey from Calcutta to Ghazipúr,* by the Reverend R. Everest.* He went across from Bancūreh (Bancoorah) to Rániganj, and briefly notices the coal pits. He alludes distinctly to the remarkable facts connected with the burnt out-crop of the Rániganj seam, and describes it as an outburst or eruption, somewhat like a volcanic eruption—"There has "been a small eruption on the side of the hill, probably occasioned by the "spontaneous combustion of the coal strata beneath. Blocks of a porous "lava, with pieces of hard slate imbedded in them, of semi-vitrified slate "sticking together, of burnt shale, red and white, and scoriæ, are "mingled in a mass not less than 130 yards across, and in some places "from 12 to 14 feet thick." The whole, or nearly so, appears to have burst forth in a line of rents under the crest of the hill, &c. &c., and he adds:—"Some time ago, in the main bed of coal, 75 feet below the surface, "the workmen had reached to within 30 yards of the Western end of "what I have described as a line of rents, when a quantity of what they "called *cinders* burst in upon them, and nearly filled the gallery in which "they were, and which has been abandoned in consequence. Cinders they "are not, but merely burnt shale, such as would be produced by heating "shale in the open air." He describes the bed of coal then worked as 8 or 10 feet thick, and thinks it probable that it was "the main bed in the formation,"—notices the peculiar structure of the coal with "an appearance of woody fibre" on the laminæ,—refers to the vegetable remains, thinking they may be ranked under the same genera as those from the English coal measures, and specially notices the impressions of

* *Gleanings in Science,* Vol. III., page 129.

the *Vertebraria*, which, he thinks, was a reed, and which he says is characteristic of the formation. He notices the occurrence of calcareous bands of sandstone; but the very limited extent of acquaintance with the field at that time may be judged from his statement, that "no dykes have yet been observed to cut the coal strata." He speaks of the Pachete Hills as "three cones which from their shape must be trap," and speculates on the probability of finding dykes proceeding from them,—alludes to the occurrence of hot springs, and concludes his brief notices, by stating that little was known of the extent or boundaries of this formation.

Dr. Forbes Royle, 1839.

Dr. Forbes Royle, in the introduction to the "Illustrations of the Botany, &c., of the Himalayan Mountains," published in 1839, briefly mentions, page 29, the coal formation of Chinnakooree (Chinakúri), and gives a section of the beds from Chinakúri to Pachete (Panchét) Hill. The section is slightly inaccurate, inasmuch as the junction of the stratified rocks and gneiss South of Panchét is not shown to be a fault: but otherwise it is correct, and it is singularly so in one respect; Panchét Hill, which has most unaccountably been described by others, and even by Mr. Williams (see below), as metamorphic or igneous, being by Dr. Royle correctly laid down, not only as of conglomerate and sandstone, but also as of a distinct series from the rest of the field. In the same work occur representations of some of the fossils obtained in the Damúda formation, viz., *Vertebraria Indica*, *V. radiata* (probably identical with the first), *Trizygia speciosa*, *Pecopteris Lindleyana*, and *Glossopteris (Tæniopteris*, or, according to some, *Pecopteris) danæoides*—all first named and figured in the work referred to.

De la Beche, 1833.

De la Beche, in his *Geological Manual*, briefly notices this field, but, as might be expected, his observations are only a repetition of those previously recorded by Mr. Everest and others, and some facts contributed by Dr. F. Royle.*

* *Geological Manual* (3rd edition, 1833), page 399.

The first Report of the "Committee for investigating the coal and mineral resources of India," appeared in 1838. The account of the "Burdwan and Adji field" is little more than a repetition of Mr. Jones's paper, with some information concerning coal in the neighborhood of the Adjai obtained from Mr. Erskine. So little was the value of the field known and appreciated at this time, although Calcutta was even then largely supplied from it, that it was considered as second in importance to the Sylhet field. It appears strange that a tract so near Calcutta should have been so little investigated by the Committee, although they were supplied with information on many points by Messrs. Homfray and Erskine. The value of that supplied by the former will be mentioned below, but Mr. Erskine appears to have directed attention to several localities previously unreported.

Coal Committee, 1838.

This Report of the Committee added nothing to the previously existing knowledge of the Geology of the field, and but little more to the information available as to its resources. Even the letter from Mr. Homfray to the Collector of Burdwan, dated 1841, and which is published as a foot-note to the Committee's Report of 1845, contains information as to several important localities where coal was worked, or had been worked, (Mangalpúr, Damúlia, Deziragurh, Narrainpúr (or Núdia), Barrákara (Chánch, &c.,) which are completely ignored in the text of the Report. It is singular to find that the Committee, who would seem almost systematically to have exaggerated all accounts of distant coal fields, should have so much neglected the far more valuable deposits in the neighborhood of Calcutta; but this may be partly explained by the circumstance that one cause of their being appointed was the difficulty of carriage by the River Damúda, and the desirability of obtaining coal from some district more easy of access.

Mr. Homfray, 1841.

In 1842, Mr. J. Homfray, already mentioned as the informant of

the Coal Committee, and who was at that time the manager of Messrs. Jessop and Co.'s colliery of Narrainkúri, contributed " A description of the coal field of the " Damúda Valley, and the adjacent countries of Bheerbhoom and Poo- " rooleeah, as applicable to the present date, 1842," to the *Journal of the Asiatic Society of Bengal.** This is the first published general account of the Rániganj field, and it lays down the boundaries with tolerable correctness, except that the coal-bearing rocks are said to extend up the Damúda to an unknown distance, thus making the Jeria field and those South of Hazáribágh parts of one great basin, whereas they are separated by wide intervening tracts of metamorphic rocks. The geological statements, however, are, for the most part, erroneous. For instance, Mr. Homfray states that there are only two workable seams of coal in the field: 1*st*, that worked at Narrainkúri, Ránigani, Chinakúri (Salúnchi), and on the Barákar and Kúdia streams; and, 2*nd*, a lower seam worked at the old Chinakúri mine and Barmúri, on the Barákar. It has long since been proved by Mr. Williams, that this statement was absurd, and, indeed, the most limited geological knowledge and the most superficial observation should have sufficed to show the distinctness of the coal seams worked at Ránigani and at Narrainkúri, within half a mile of each other. Again Mr. Homfray declares the Salma trap dyke† to be a great fault, and that the " upheave is evidently to the North-east." Nothing can be clearer than the total absence of any " throw" whatever. One more instance will suffice. Mr. Homfray says, page 725, " At some " distance up the Damúda River, on the South-west bank, is the " great hill of Pachete, from which innumerable dykes issue, and all " around its base and between it and the river, a space of about " 4 miles, the country, although abounding in coal, is full of these " dislocations." It is curious that the country between Panchét (Pachete)

Mr. J. Homfray, 1842.

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* Volume XI., page 723.

† Page 725.

Hill and the river is perhaps more free from trap dykes than any other portion of the whole field, and there are no indications of an unusual amount of faulting. The hill itself, as already mentioned, is of sandstone.

Mr. Homfray, 1847.

A second paper, published by Mr. Homfray in 1847, is merely a recapitulation of his former errors. Beyond some details of the extent of the field, neither paper contains any information of value.

Dr. J. Hooker, 1855.

A few remarks by Dr. Hooker occur at Volume I., page 7 of his *Himalayan Journals**; they, however, simply refer to the uncertainty of all determinations of the age of rocks, when dependent solely upon the evidence of fossil plants.

1845.

Previously to the final Report of the Committee in 1845, there had been but little addition to the information, and the Committee then expressed the want of any thing like a regular account of the beds of coal in the field. The subjoined list of coal localities was given (page 103):—

Damooda ...	1 Singharun River	A mile from the junction of the Damúda ...	7 feet.
	2 Barracara ...	Burmúry Village ...	8 or 9 feet.
	3 Raneegunge ...	7 miles above Singharun Nulla ...	9 feet.
	4 ——— ...	5 miles above Raneegunge ...	7 „
	5 Chinakúri ...	5 miles below the confluence of the Barracara River ...	7 „
Adji River ...	6 Churalya ...	¼ of a mile from the South bank of the Adji ...	6 „
	7 Moheednuggur	North bank of the Adji, ¼ of a mile from the river ...	13½ „
	8 Mammudpore ...	2 coss South of Seedpûr Ghât ...	Size not stated.

With reference to these, the information regarding No. 1 is probably incorrect—no seam is known in any such locality. Perhaps Mangalpúr is referred to, but this place is stated in a note by Mr. Homfray to be 5 miles from the Damúda. The bed at No. 2, Barmuri, is nearer

* Edition of 1855.

20 feet thick in reality—that at Rániganj is 13 feet, not 9. No. 4, although no name is here given, is evidently intended for Salma (see page 149), where a bed of 7 feet was stated to occur; but Mr. Homfray failed to reach it, although he sank to a depth of more than 200 feet. It is doubtful if any such seam occur in the locality. The bed at Churalya, No. 6, has not hitherto been worked to any extent, but was opened out last year—that at Moheednuggur is probably the coal now known at the Kásta quarries; but the seam there is above 30 feet thick. No. 8, Mammudpore, is Mahamudpúr, near Chokidánga.

Mr. D. H. Williams, 1847.

In 1845 and 1846 the Rániganj coal field was first carefully examined, mapped, and reported upon. Mr. D. H. Williams, who had been attached to the Geological Survey of Great Britain, and had, in connection with it, been engaged in the examination of the South Wales coal fields, was appointed Geological Surveyor to the Honorable East India Company, and was dispatched to Bengal, where he arrived in 1845. His Report,* dated 7th December 1847, was not published till 1850, after his death, and it was printed in England. It is full of type errors, especially as regards names of places. It is, moreover, by no means clearly written, and so deficient in arrangement as to be almost unintelligible to any one unacquainted with the district. But, considering the circumstances under which the Report was printed and published, these defects are scarcely chargeable to Mr. Williams. On the other hand, the statements are, for the most part, accurate; the various rocks are well and clearly described, and, in general, the relations of the different beds to each other are correctly made out. It will, however, be necessary to point out in some detail what errors existed in Mr. Williams's Report.

His Report.

* A Geological Report on the Damoodah Valley, by D. H. Williams, Esq., London. Printed by order of the Court of Directors. This Report was subsequently reprinted in Calcutta, 1853.

The Geological map, which also bears the date of 1847, was published in India, together with some horizontal sections, and a vertical section of the whole of the strata contained in the field. Of the map, considering that the topographical and geological work was necessarily carried on at the same time, it is difficult to speak too highly. The boundaries are mostly true and well mapped; the coal seams correctly laid down. The sections, however, show what is also evidenced by the Report, that Mr. Williams, while he clearly understood, and satisfactorily explained, many of the geological problems presented by the field, still remained in error on several points of detail. Although he clearly saw the relations of beds to each other in particular localities, he did not reconstruct the general section accurately, and he was occasionally misled by applying his English experience too literally in the explanation of the various phenomena which he observed. But his Report is of so much importance, both in consequence of the large amount of detailed information which it contains, and also of its being the only account of the Ránigarj field on which any reliance could be placed, that a recapitulation of its contents is essential, in order to show what knowledge existed on the subject of the coal field of the Damúda before the commencement of the present survey.

His Geological Map.

Abstract of Report.

The Report commences with a description of the physical geography of the district. This is followed by an account of the gneiss and metamorphic, or, as Mr. Williams terms them, "the inferior stratified rocks," perhaps the least accurate portion of the whole Report. It commences thus:—

Metamorphic Rocks.

"The lithological composition of those ranges which environ the coal "field is as follows:—On the North side of Telindah Village, in the bed "of the Damoodah River, the rocks are constituted of nodular syenitic "greenstone, arranged in four parallel bands, separated from each other

" by thick beds of light-grey felspar, both soft and decomposed ; these " beds appear to me to compose the contents of the great South or boun- " dary fault. Proceeding to the West, in the direction of Telindah or " Medjeah, these trappean beds are composed of compact contempora- " neous conglomerate, with a brownish-grey base, containing large " rounded boulders and pebbles of quartz and granite of various colors, " and occasionally pebbles of jasper and fragments of mica-schist: pieces " of a similar conglomerate are found along the whole line of the great " South fault, up to the base of Pachete Hills."

This is in several points erroneous, it represents the "great South or boundary fault" as being *composed* of "nodular syenitic greenstone," &c. The rocks South of the fault are frequently hornblendic, and sometimes syenitic, but the fault itself is a mere crack, despite its enormous throw. It does not even contain a breccia, as is the case with many large faults in the gneiss. The expression, these "*trappean* beds are composed of *compact contemporaneous conglomerate*," &c., must either be a misprint, or else have arisen from some mistake about terms, otherwise it would involve a no less serious error than that of confounding together metamorphic, trap, and ordinary stratified rocks. This is indeed one of many cases in the Report in which the inaccuracy is, in all probability, due to the want of Mr. Williams's supervision during publication. In his map he has erroneously colored Behárináth, Garangi, and Panchét Hills as gneiss; and not only has he so colored these hills, which, from their difficulty of access, he appears not to have examined closely, but he has committed the same error with the small hill of Telinda, on the banks of the Damúda, a little below Rániganj, although, from the mention he makes of the spot, there can be no doubt that he visited it. The only reason which can be assigned for this mistake is the circumstance of the coarse sandstones and conglomerates (which form all these hills, and are very different in character from those prevailing in other parts of the Rániganj field,) being frequently much contorted and turned

up at high angles in the immediate vicinity of the boundary fault. But they are distinctly confined to the North side of the faults, and belong to one of the highest groups of sedimentary beds in the field. It was a mistake to suppose them to have any connexion whatever with the fault, or with the metamorphic rocks.

The next five pages are devoted to an account of the distribution of the gneiss and other hypogene rocks, South, West, and North of the coal field.

Coal measures.

The description of the coal measures, which comprises the greater portion of the Report (from page 17 to page 92), follows that of the metamorphic rocks. It commences by specifying the beds seen about Khyrasol, about 15 miles East of Ràniganj, where sandstones first rise from beneath the laterite and alluvium of the delta which conceal them further to the East. These rocks, as will be shown hereafter, are, in all probability, distinct from all the beds associated with the coal, a fact of which Mr. Williams was not aware; he mentions, however, his having been unable to discover the least indication of coal, and relates the ill success of the borings near Kálipúr, by the Bengal Coal Company and by Messrs. Erskine and Co.

The general description proceeds—"From thence (the neighborhood "of Khyrasol) in a Westerly direction, towards the Barákkur, and subse-"quently returning along the North bassets of the field."

The occurrence of sandstones South of Andál, with a slight Northerly dip, and the discovery of coal at Jánjura, at a depth of 20 feet from the surface, are considered by Mr. Williams as evidence that the whole area between Andál, Khyrasol, Ukra, and Jánjura contains coal measures. The ferruginous conglomerate (laterite) of Baktarnagar is mentioned, and a description, with sections, given of the rocks associated with the coal of Mangalpúr. The extension of the seam to Harispúr is correctly inferred from borings, but the line of outcrop shown on the map, extending from Mangalpúr to Harispúr, is inaccurate.

From Mangalpúr the description proceeds up the Singáran Valley with details of the various sections seen, and of the coal seams mined at Dhosul and Chokidánga, the only collieries at work in 1845. The assertion of the "Damúda Committee,"* that only one workable seam of coal exists on the Singáran, is shown to be wrong.

From the description of Chokidánga, Mr. Williams proceeds to that of Sírsol (Searsole), then recently opened. He considers the seam identical with that of Ráníganj. Reasons for differing from this opinion will be given hereafter. Some passages in this portion of the Report show that Mr. Williams was impressed with an idea derived from his experience in England, that disturbance or faulting always accompanied the trap dykes. It is, however, clear from other parts of the same Report, that he observed the facts correctly, and, wherever sections were visible, satisfied himself that in this field the trap dykes, *as a rule*, are accompanied by no throw whatever. At the same time he had obviously not entirely got rid of his earlier impressions, and he therefore speaks with great hesitation as to the chances of success in the Sírsol (Searsole) mine, owing to the immediate proximity of several dykes. And a little further on, he speaks of the bed of coal discovered by Mr. Jackson, close to Bashrah (Bánsra), as cut off "on the North from the coals at Mungulpore and Khantagoriah by "several dykes running East and West, and on the South other dykes "occur," &c. This seam has never been worked in the spot mentioned, South of the Grand Trunk Road. It is, in all probability, the same as that worked to the North of the road at Gopinathpúr and Bhángaband (formerly known as Khantagoriah.)

The next coal locality described is Rogonathchuk, South of Bansra, the seam at which place is considered, probably with justice, to underlie

* The Damúda Committee was appointed August 1846, to report "On the inundations and the state of the embankments of the Damúda, and on the means of communication by land or water between those districts and Calcutta." It consisted of Major Sage, Mr. F. W. Simms, and Dr. McClelland.

those at Narrainkúri and Ráníganj. Mr. Williams mentions the discovery of a fossil plant, which he considered a *Sigillaria*, but it was much decayed, and it is probable that he was deceived by an accidental resemblance. Several pages are here devoted to the refutation of an absurd statement of the Damúda Committee, to the effect that the seams at Rogonathchuk and Khantagoriah (Bhángaband) were proved to be identical by the similarity of the associated fossils. This Mr. Williams disproves: 1*st*, by showing that the same fossils may be associated with all the coal seams in a formation; 2*nd*, by the dissimilarity of the sections of the two coal seams.

In reference to this question, there occurs the only remark in the Report, in which the fossil plants, so abundant in the coal series, are referred to in general terms—it is as follows:—

"The fossil impressions found associated with the coal measures of "the Damoodah Valley have been carefully examined and compared "with those discovered in the English coal districts, and are found "to have no resemblance whatever to them, the most characteristic "species are *Trizygia speciosa, Vertebraria indica, Vertebraria radiata,* "(plants of a doubtful affinity,) *Glossopteris angustifolia, Glossopteris* "*Browniana, Pustularia Calderiana,* and *Pecopteris Lindleyana;* there "are also several impressions of leaves, reeds, and others of the cyca-"deous family. Plants of the above genera have never yet been "discovered in the coal fields of Europe, but this Flora approximates "nearer to the Coal Flora of Australia, where similar cycadeæ, several "species of *Glossopteris,* and *Vertebraria,* have been discovered. It "may be interesting further to state that *Glossopteris* is a genus "common to the oolitic series of England."

To criticise this passage at length is unnecessary, and would require too much space: the subject has already been treated sufficiently by Dr. Oldham.*

* Mem. Geol. Surv. of India, Vol. II., pages 299 *et seq.*

Rániganj mine.

A short description of the Rániganj mine succeeds, with an account of the destruction of the old mine by fire in 1843. A series of experiments under Mr. Williams's superintendence were made in this mine, upon the introduction of the English system of ventilation.* The successful results in cooling the mine are shown from thermometrical observations.

In the next pages Mr. Williams describes the coal worked at Narrainkúri, and shows that the Rániganj and Narrainkúri seams are clearly distinct and not identical, as had till that time been supposed. He then details the beds seen in the Núnia, from its mouth on the Damúda, as far as the suspension bridge on the Grand Trunk Road, and proceeds to describe the rocks developed West of the Núnia, and South of Asansol. He observes that "these beds are composed of "arenaceous shale, with alternating beds of *red marl,* and beds of "greenish-grey sandstone, highly micaceous and soft," (page 531).

The area covered by these (the Panchét series of our classification),† both North and South of the Damúda, is accurately described, with the exception of the omission of all mention of their occurrence at the base of Beharinath and Panchét Hills. Their place in the general series was somewhat misappreciated by Mr. Williams, as is shown by his sheets of vertical sections. This error, however, applied more particularly to the rocks of the neighborhood of Rániganj, since the rocks were traced downwards with perfect accuracy from the Panchét series to the base of the Damúdas, in the Western parts of the field, where alone sections are well seen.

A detailed section of 2,747 feet of the rocks near Chinakúri, which are considered to be the lower beds of the middle coal measures, is next given: then an account of the beds near the Núdia colliery, South of the Damúda, and a measured section of those

* Ultimately these experiments were the cause of great danger to the mine, from the small coal, which had been used to form stoppings in the galleries, having ignited.

† *See* further.

seen in contact with the fault bounding the field to the West. Mr. Williams proceeds to mention the coal seam at Chánch, and to refute some statements of Mr. Homfray concerning its mode of occurrence. In doing so, however, Mr. Williams may perhaps be in error himself in considering the Chánch seam to be *necessarily* co-extensive with the ironstone shales, the base of which is stated to be 340 feet higher in the series, and the area covered by which is mentioned. Mr. Williams believed that, "according to a well-known established fact in Geology," the coal underlies the ironstones for "several hundred square miles to the East and North-east." The recent examination, conducted more closely, and altogether under more favorable circumstances than existed at the time of Mr. Williams's survey, has induced the belief that coal seams in the Damúda field generally, and especially in the lower portion of the series, are not continuous equally over large areas. And also that there is considerable probability of the existence of unconformity between the ironstone shales and Lower Damúda rocks, the latter containing the Chánch seam: there is therefore much reason to doubt the correctness of the opinions expressed upon this point.

The great mass of carbonaceous shales and ironstones receive only a passing notice. The Report proceeds thus:—

"Having descended through the series of rocks above noted, which "are analogous to the lower coal-measures of England and elsewhere, "and rich in both coal and iron mines, a fact which would have "considerable influence on the passing observer and induce him to "suppose that he had arrived at the base of the productive coal-"bearing measures, especially as the sandstones and conglomerates "underlaying them exhibit a close analogy to the millstone grit or "farewell-rock series, in which no coal of any commercial value was "ever found: the beds generally entombed in this part of the carbo-"niferous formation are thin and very inferior in quality, varying in

"thickness from a few inches to about three feet, and the greatest "number of beds found in a single coal field has not exceeded two or "three at the utmost. In the Damoodah Valley it will be shown that "beneath the black and grey argillaceous shales previously adverted to, "there is a considerable deposit of coal-bearing measures, principally "composed of sandstones and conglomerates, subordinate beds of shale, "seams of coal, and thin beds of argillaceous limestone, resembling in "mineral character the nodular limestone of the lias, but these calca-"reous accumulations appear to be devoid of organic remains."

A measured section of 4,097 feet, embracing the lower 1,000 feet of the iron shales, all the lower coal-bearing series, and the Talchir group (see below) is given to show the constitution of the lower measures, and a detailed account of eighteen coal seams contained in them follows. A great portion of this section was deduced from a series of pits sunk by Mr. Williams in the neighborhood of Táldánga. Of the eighteen coal seams only four are stated to be composed of superior coal.

Mr. Williams here enters into the question, whether the "lowest coal-bearing strata" (of the Damúda field) should be placed on the parallel of the millstone grit (of England), or one step higher in the series. With regard to this subject the following is worthy of extraction, as showing what opinion he held upon the subject:—

"The great difference existing between these shales and those of "England, is simply this: there they contain all the productive beds "of coal commonly developed in the rock termed lower-measures; "and in the Damoodah the lowest coal seams are developed in the rocks "inferior in position, and have a greater thickness than the whole "quantity contained in the great coal field of South Wales. With this "anomaly, together with the absence of the carboniferous limestone, "it must be confessed that it is no easy question to decide a point of "so much scientific importance. It would seem premature in the "present state of the investigation to arrive at a definite conclusion, or

" that we should expect to find the geological equivalents of the English " series of coal measures to square exactly in detail with those in a " distant country like India."

The coal at Sangamahál is noticed, but Mr. Williams does not appear to have known of the remarkable section on the Kúdia, South of Nirsha, nor to have visited the extreme West of the field.

The beds at Jariagarh, West of the Rániganj field, are stated to possess the same lithological characters as those developed at the base of the Damúda field.

" The greenish-grey argillaceous shales, constituting the fundamental " rocks of the series, are also seen at Jurreahghur to occupy the base " of the measures; and, supporting beds of conglomerate and quartzose " sandstones, are thick beds of coal, stated in my first Report to have a " thickness of at least 40 to 50 feet."

A section of 837 feet, from the neighborhood of Lálbazár, East of the Barákar, and embracing the uppermost portion of the lower coal-bearing series, is given, and compared with the section previously given from the neighborhood of Táldánga, West of the Barákar, and about 6 miles distant. The identifications of coal seams are, however, for reasons already mentioned, open to much doubt.

Mr. Williams has thus nearly completed the circuit of the field. A few remarks on the coal seams, &c., of Lálbazár, and the bands of beds of the lower measures extending thence to the Adjai, and recurring through the intervention of a fault North of that river, in the neighborhood of Kásta, Afzalpúr, &c., conclude the description. Mr. Williams calls attention to the occurrence of a " fresh water limestone" containing unios on the East of the Barákar, near Rámnagar, and its identity with the *kunkur* of the plains of Bengal, and he also describes the greenish-grey shales with calcareous nodules (*Talchir* beds) near Dabúr North of Samdi, and observes their absence at the base of the series North of the Adjai, near Afzalpúr, &c.

Pages 92 to 100 are occupied with a short account of the alluvium. Kunkur and laterite are briefly alluded to, but his remarks are chiefly directed to the agriculture and population of the district. A chapter on faults and dykes succeeds. The two were evidently, as already remarked, confounded to a certain extent, for not only does Mr. Williams include them under the same head in his description, but he used precisely the same symbol, a white line, to represent them on his map. He enumerates twenty-seven large dykes, which are but a small proportion of the whole number in the field, and some of those marked are not very correctly laid down in the map. A large tract in the North of the field, extending from Múktochandi Hill to Etiapúra, is colored by Mr. Williams as trap, and considered by him (page 105) as probably a continuation of a "broad belt of altered sandstones seen on the North "of Churooleah." The true nature of this tract, a country cut up by numerous trap dykes, will be hereafter referred to.

Some twenty-five pages of the Report (pages 106 to 131) are occupied with the "Conclusion," and from it we may gain some idea of Mr. Williams's geological views, especially by connecting it with the sheets of sections, vertical and horizontal, above referred to, which accompanied the map. The first portion refers to the absence in Bengal of Cambrian and Silurian rocks, old red sandstone, and carboniferous limestone. The geological ideas expressed concerning the mode of formation of the sandstones, conglomerates, and coal, are, and were, at the time the Report was written, antiquated, and need not be repeated; but the following list of coal seams is worthy of extraction:—

Upper Measures.

					Ft.	in.
1. Mungulpore seam	...	...	...	...	22	0
2. Khantagoreah ditto	...	...	...	...	7	0
3. Kendah ditto	...	...	...	...	2	9
4. Coal under ditto	...	...	...	...	3	6
				Carried over ...	35	3

Brought forward ...	35	3		
5. Coal under ditto	4	0		
6. Dussul ditto	26	0		
7. Rogers' seam	12	0		
8. Chowkedangah ditto	15	8		
9. Coal under ditto	4	0		
10. Raneegunge	9	0		
11. Two beds under ditto	3	9		
12. Naraincoory ditto	13	0		
13. Rogonathchuk	12	0		
			134	8
Middle Measures.				
14. Marooleah seam	8	0		
15. Ditto	1	4		
16. Saloonchy top bed	1	1		
17. Ditto, thick bed	10	6		
18. Cheenacoory	7	2		
19. Coal under bed	1	0		
20. Ditto ditto	3	0		
21. Ditto ditto	4	0		
22. Ditto ditto	0	6		
23. Ditto ditto	0	6		
24. Ditto ditto	1	9		
25. Ditto ditto	4	0		
26. Ditto ditto	2	9		
27. Ditto ditto	0	6		
28. Noodeah coal	11	6		
			57	7
Lower Measures.				
29. Coal	1	0		
30. Ditto	2	0		
31. Doomer Koondah seam	12	0		
32. Coal under ditto	1	0		
33. Ditto ditto	10	0		
34. Ditto ditto	6	0		
35. Ditto ditto	5	6		
36. Ditto ditto	4	0		
37. Ditto ditto	0	11		
38. Koomerdooby coal	9	0		
40. Coal under ditto	1	4		
41. Coal	0	8		
42. Coal in two beds	2	0		
Carried over ...	55	5		

Lower Measures.—(Continued.)

	Brought forward ...	55	5	
43. Taldangah coal	... ...	10	0	
44. Ditto ditto	... ...	7	6	
45. Coal	... ...	3	0	
45. Ditto	... ...	9	5	
46. Ditto ditto	... ...	13	0	
47. Under ditto	... ...	16	6	
48. Coal, No. 2	... ...	12	0	
49. Coal, No. 1	... ...	20	0	
50. Coal under ditto	... ...	15	0	
				161 10
	Total			354 1

The Coal Committee are most deservedly reproved for their views as to the superior quality of coal being dependent on, or connected with, its altitude above the level of the sea and the disturbance it has undergone. They, with a logic perfectly consonant with the appreciation which they throughout shewed of the value of evidence, considered that the most conclusive proof of the presence of the lowest members of the coal measures from which they believed the best coal to be obtained, was the position of those "coal measures" on the tops of mountains, the highest measures, on the contrary, being found in the low-lands of the country. So wild a statement might fairly have been left to be judged by the self-evident contradiction which it involved. Mr. Williams proves from the South Wales coal field that good seams may be just as abundant in the upper as in the lower part of the coal measures.

Points decided by Mr. Williams.

As no published additions of any importance have been made to our knowledge of the geology of the Ráníganj field since the publication of Mr. Williams's Report, it may be well to state briefly what was established by him.

1*st.*—He clearly showed a great succession of beds, the whole of which, with one exception (his "upper measures"), he interpreted

correctly. From his vertical section we may take the following as an abstract :—

Upper Measures.

		Feet.	
Beds of Singharun Valley	about	1,500	
Ditto Rániganj, Narrainkúri, and Rogonáth chuk		500	
			2,000
Middle Measures.			
"Measures containing red marl unexplored"		800	
Ditto ditto Marúlia and Bágalgoria coal		1,600	
Ditto ditto Salúnchi (Chinakúri new) coal ...		600	
Ditto ditto Chinakúri ditto, and thence to top of the carbonaceous shales, containing ironstone, including all the beds seen North-west of Chinakúri, the Núdia coal, &c.		2,300	
			5,300
Carbonaceous shales and ironstones			1,000
Lower measures		2,500	
Conglomerates and greenish-grey shales (Talchir)		700	
			3,200
Total ...			11,500

It will be seen that, although some difference in the exact figures may occur, the above has, in the main, been perfectly confirmed by the results of the present survey—always with the exception of the upper measures of Mr. Williams, which will be shown to be equivalent to the beds in the neighborhood of Chinakúri forming the central parts of his middle measures.

2*nd.*—The great faults cutting off and bounding the coal-bearing rocks on the South and West were correctly determined and mapped, and the general geological structure of the field and its Southerly dip clearly shown by the sections.

3*rd.*—The various coal seams were, in many cases first discovered, in all cases first mapped. Several additional seams have, however, been discovered since Mr. Williams's survey.

4*th.*—Many of the errors of Mr. Homfray and of the Coal Committee were exposed and corrected.

5th.—The occurrence of the great band of carbonaceous shales, containing ironstones, and their position in the series, was determined. The "greenish-grey shales" of the Talchir group were noticed, as also their absence in the North-eastern portion of the field.

But, on the other hand, several important geological facts were left undetermined. The greenish-grey shales and conglomerates, (now recognized as belonging to the Talchir group,) and the beds containing red marls, (here described as the Panchét group,) were observed, but were not separated from the other rocks, sufficient importance not having been attached to the evidence of their unconformity with the true Damúda series. The separation caused in the general series by the band of ironstone shales was not given sufficient prominence, and the beds of Rániganj and of the Singhárun Valley were entirely misplaced. Mr. Williams was also led by his English experience erroneously to anticipate that faults would be found co-existent with trap dykes, and that the coal seams would be found equally co-extensive with the beds accompanying them. The map is also erroneous in representing Panchét (Pachete), Behárináth, Garangi, and Telinda or Madjia Hills, as gneiss. The boundaries generally required greater exactitude. But such detailed errors of mapping are more than excused by the difficulties under which he labored. No topographical map of the country existed: that published was laid down during the progress of Mr. Williams's survey, and the geological work was frequently in advance of the topographical, and had to be put on paper subsequently.

Questions left undecided.

As regards the geological relations of the beds of the Damúda field with those in Europe, Mr. Williams appears never to have doubted that all the Indian coal-bearing strata belonged to the same age as the carboniferous formation of European geologists. One or two extracts have already been given. The following, however, appear conclusive.

"In Lower Bengal there is not the least indication of those enor- "mous accumulations of sedimentary matter, formerly known as the "primary fossiliferous strata, to which, however, the more appropriate "names Cambrian and Silurian have of late years been applied; these "grand divisions embrace the whole mass of detrital matter, from the "old red sandstone to the inferior stratified rocks. It is also essen- "tially necessary to mention that both the old red sandstone and carbo- "niferous limestone are likewise absent in the districts which have "been examined. (P. 107).

"But prior to the deposition of the coal series, there can be little "doubt that the area now occupied by them had been elevated above "the surface of the surrounding ocean during those epochs of time "which have elapsed from the first organization of animal life on the "crust of the globe to the commencement of the coal-formation era." (P. 109).

He only questioned (page 82), whether the minor sub-divisions were precisely parallel in the two countries. Nothing throughout the Report seems to convey any question as to the general age of the deposit.

It is evident that Mr. Williams's attention was principally directed to the economic geology of the district. His main object was to examine and ascertain the quantity and quality of coal and iron ore available. On these subjects his Report leaves less to be added, and would leave scarcely anything, but that more extended exploration for commercial purposes has enabled the present survey to add enormously to the previous knowledge of the mineral wealth of the district. But upon the geological structure an amount of light has been thrown by the examination of the various districts of the Narbadda, the Rájmahál Hills, and Talchir (Cuttack), which enables the rocks associated with coal in the Damúda Valley to be placed on a distinct and definite horizon with respect to many of the other rock systems of India. And the examination of the Rániganj field, while it has borrowed from previous

explorations, has richly returned the loan by the assistance which its rocks, read by the light thus discovered elsewhere, have given to the further elucidation of other areas.

The description of the Geology of the Ràniganj basin is given in detail in the following pages.

CHAPTER II.—*General Topography and Geology.*

Position of field.

THE area of coal-bearing rocks, known as the Damúda or Ràniganj field, lies between latitude 23° 35′ and 23° 45′ North, and longitude 86° 40′ and 87° 15′ East, and at a distance of from about 120 to 160 miles North-west of Calcutta. Its greatest linear extent is from W. by N. to E. by S.; the length of which, from near Gyra dâk bungalow, on the Grand Trunk Road, and from Girwa Hill on the West, to the extreme point towards the East at which coal is known to occur, viz. the neighborhood of Harispúr, is 39 miles; but there can be no doubt of a considerable extension further East, although it is concealed by over-lying laterite and alluvium. How far it extends is uncertain; a careful examination of the surface has only shown that the few rocks seen about Khyrasol, and from thence towards Ukra, are distinct from any beds seen within the area of the field. They are, doubtless, higher, but whether coal-bearing rocks underlie them or not, cannot be positively ascertained by an examination of the surface.

Extent of field.

The greatest breadth on a line at right angles to the above is from the neighborhood of the Adjai, north of Churalya, Madanpúr, Domaháni, and Panúri, to Behárináth Hill, or from Afzalpúr to near Gúsra and Kastúra, a distance

of 18 miles in each case. The area contained in this belt of somewhat irregular breadth is about 500 square miles.

Geology.

The general geology is simple. A series of between 11 and 12,000 feet of rocks, dip in succession from the Northern boundary, at angles varying from 5° to about 20° towards the South. All are suddenly cut off at the Southern boundary by one of the largest distinct faults that has ever been carefully observed and recorded. There is some crumpling of the strata near this fault, and at about 4 or 5 miles North of it, there is a roll of the beds throughout a considerable area. The dip changes from S. S. W. in the East of the field and to the North of Ràniganj, to S. S. E. as it approaches the Barákar, West of which river it recurs to S. S. W. : the general direction of the dip throughout being, as already stated, Southernly. It increases in amount considerably towards the West, causing great contraction in the width of the field, the same thickness of rocks, or even more, cropping to the surface between the North base of Panchét Hill and Débitan on the Barákar, a distance of 10 miles,* or between Hirapúr, East of Chinakúri, and Dendwa near Jamiari, a distance of 9 miles, as between Kastúra, South of the Damúda, and the boundary North of Birkúnti, on the Adjai, a distance of 16 miles.

Great S. fault.

The greater portion of the field is enclosed between the Rivers Damúda and Adjai. South of the former a band of sedimentary rocks, 6 miles wide, where broadest, stretches from the stream to the base of a range of small hills of metamorphic rocks. This range is by no means continuous, and in places recedes considerably from the boundary, being, as are most hills in the metamorphic rocks of Bengal, parallel to the strike of their foliation, which does not always exactly coincide with the direction of the fault bounding the field to the South, although there is a general parallelism: North of the Adjai the lowest portion of

* In a direction somewhat transverse to the line of dip.

the beds is repeated by a fault, which follows the course of the river. Only a thin band, however, of the rocks can be examined, a considerable breadth of the Adjai Valley, South of Afzalpúr, and further East, being occupied by alluvium. Another fault, still further North, brings in a second strip of rocks, which, however, appears to be separated throughout from the first by a band of metamorphic rocks.

Principal drainage.

The principal drainage of this small area flows into the Damúda, the water-shed between which and the Adjai runs in most places only 4 or 5 miles South of the latter river, and consists of a range of high ground, composed, for a considerable distance, of a band of carbonaceous shales containing ironstones, which will presently be described. Within the boundaries of the field the Damúda receives the Barákar, a river but little inferior to itself in size, and two smaller streams, the Núnia and the Singáran: the course of the former of these two and of the three streams, which, near Asansol, combine to form it, is entirely within the area of the field, and that of the latter only leaves the coal-bearing rocks to pass in the lower part of its course, through a tract of alluvium bordering the Damúda. The Barákar, near its confluence with the Damúda, receives the Kúdia, which, with its tributary, the Pasai, drains the West of the field. From the South the Damúda receives several small streams, most of which rise in the metamorphic country to the South of the boundary.

The surface of the field is undulating, and was formerly covered with jungle, which has now been cleared nearly throughout. It is generally covered with clay, in some parts alluvial, but in others formed from the decomposition of the rocks. This covering is in general much thicker upon the beds hereafter to be described as the "Ráníganj series," and upon the upper portion of the "Panchét beds" than upon the Lower Damúda or Talchir rocks, while generally it is wanting upon the carbonaceous shales containing ironstone bands. In many

portions of the country, and especially in the large tracts occupied by rocks of the Ránigánj series, North of the Damúda, (with the exception of the valley lying North of Chinakúri, portions of the Núnia Valley, and some small valleys, immediately North and West of Ráníganj,) this clay, whether alluvial, or produced by surface action, restricts all geological researches to the banks of streams, and even these frequently show but little. The circumstance of its being so much more generally spread upon some rocks than upon others shows it to be due, in part at least, to the effects of surface action upon the beds; soft sandstones abounding in felspar apparently becoming easily converted into clay, while, as might have been expected, shales and quartzose sandstones resist decomposition.

Principal hills.

Along the South border of the field, and abutting against the fault, are two isolated hills of considerable size, and two smaller ones, composed of sedimentary rocks. The largest of these, Panchét (Pachete) Hill, is at the South-west corner of the area occupied by the Damúda beds and their associates. It is about 1,600 feet high and 2 miles long. The scarp towards the North is precipitous, and marked by terraces, corresponding to the outcrop of beds of hard conglomerate;* the other sides are also very steep, the top about 2 miles broad, comprising an undulating tract of dense jungle. Behárináth Hill is 10 miles to the East of Panchét; it is of rather less height (1,481 feet), and of much smaller extent. Garangi Hill, between Panchét and Behárináth, is of inconsiderable size, and Telinda Hill, or, as it is often called, Madjia Hill, South-east of Ráníganj, is still smaller. Each of the larger hills has a thick cap of a peculiar conglomerate, and the two smaller hills are entirely formed of it.

* These were noticed by Mr. Williams, who speaks of "well-defined contour lines of, apparently, stratification, running parallel with each other, and extending along the whole length of the North side." It is clear from his Report that Mr. Williams never actually visited Panchét Hill.

Excepting these, the only rises within the field are some low hillocks not exceeding 60 feet in height, formed by hard conglomerate

Smaller elevations.

bands in the neighborhood of Nirsha, in the extreme West of the area; the rounded ridge of ironstone shales about 4 miles South of the Adjai already mentioned; the low laterite hills of Baktarnagar, Mangalpúr, Harispúr, and other places near the Singáran Valley, or East of it; and the little mass of trap near Samdi, which is known as Muktichandi Hill.

The rocks beyond the boundaries of the field belong to the metamorphic series, and consist of different kinds of gneiss, hornblende rock, quartzite, &c., similar to the formations covering the greater portion of Bengal, (excepting the alluvial plains bordering the Ganges and its tributaries,) Orissa and most other tracts in the East and South

Rocks.

of the Peninsula of India. They have been referred to frequently in preceding Memoirs, and until the time shall come for a full general description to be published of them, but little additional information can be conveyed by isolated remarks upon small and detached areas.

The following pages will contain a detailed description of those rocks alone, which are comprised within the boundaries of the Ràniganj field. How those boundaries run, what their direction is, where they are faulted, and where natural, can be learned more quickly and more accurately from a glance at the map than from a prolix verbal description.

The remaining sections of this portion of our Report will be devoted to the rocks of the Ràniganj field, embracing mainly the Damúda group and its associates. Before proceeding to describe these in detail, it will be well to state succinctly into what divisions the beds may be grouped. These are the following, commencing from the bottom:—

Talchir rocks.

1. At the base of the field, in places, and resting upon the metamorphic rocks, there occur greenish-grey muds and fine sandstones, occasionally containing

boulders. These are easily recognized by their mineral character as belonging to the Talchir group.*

Damúda rocks.

2. Above the Talchir group comes a great thickness of beds containing coal. By both mineral character and fossil contents, these are recognized as of the Damúda group.† Reasons will hereafter be given for concluding that in this field only the lower portion represents that group as developed in neighboring localities, as on the flanks of the Rájmahál Hills, and in Orissa. To this portion will be restricted the name of Lower Damúda.

Ironstone shales.

Above the Lower Damúda sub-division are found beds markedly distinct in mineral character, and at the base of which there is a considerable thickness of carbonaceous shales, with ironstones, the band already alluded to as the ironstone shales. In the presence of coal in large quantities, and, despite some minor distinctions, in their fossil contents, these beds are closely allied to the Lower Damúda rocks, and they might well have been named "Upper Damúda," had not that term been already

Ránigani rocks.

applied to a series of beds occurring in the Nerbudda district, which there is every reason to suppose are distinct from, and more recent than, the upper portion of the Damúda group in the Ránigani field. For these, therefore, as they contain all the most important coal seams now worked in the neighborhood of Ránigani, and as they are well developed around that station, the term "Ránigani series" appears appropriate.

3. The Damúda group is over-laid by grey and greenish sandy shales, and upon these rest coarse false-bedded sandstones, with deep red clays.‡ These beds are clearly quite distinct from the true Damúda

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* See Memoirs, Vol. I., pp. 46—56, 76—80, &c., Vol. II.

† *Jour. Asiat. Soc.*, Beng., Vol. XXV., p. 249. *Mem. Geo. Surv.*, India, Vols. I. and II.

‡ These are termed marls by Mr. Williams in the same way as the clays of the Trias (which the beds of the Panchét group much resemble,) are known as "New Red Marls" in England. The term, however, is not quite correctly applied in either case, the clay not being calcareous.

rocks; their Flora, so far as known, shows an almost complete change, and animal remains of reptiles, fish, and crustaceans, have been discovered in them. They are also completely distinct in mineral character, and contain no coal seams. For these beds, which, although noticed and described by Williams, have not, until now, been separated as a distinct group, the name *Panchét* is proposed, from the fine hill of Panchét, the lower portion of which consists of them. The village of the same name, just South of the hill, is the residence of a Rajah, whose predecessors owned a large portion of the area of the coal field, and a considerable proportion is still included in his estates.

Panchét series.

4. In the hills already mentioned near the South boundary of the field, (Panchét, Behárináth, and Garangi,) the clays and sandstones of the Panchét group are capped by coarser sandstones with conglomerates. It is possible that these also belong to the Panchét group, the upper beds of which are in places very similar; but this is quite uncertain, and some reasons will hereafter be given for supposing that these beds may be of the same age as the lower portion of the Rájmahál group,* to which, though with considerable doubt, they may be provisionally referred.

Panchét grits.

5. The higher rocks which occur are: 1*st*, a series of very coarse ferruginous sandstones, with mottled clays, which form a high ridge near Khyrasol, East of Ránigánj, and are but ill seen, being mainly covered and concealed by laterite; 2*nd*, the laterite itself; 3*rd*, alluvium in various forms. Each must receive a short notice, but the main object of the present Report is the description in detail of the Damúda beds, and their immediate associates of the Talchir and Panchét groups.

Upper rocks.

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* In the belief that these beds might be merely an upper series of the Panchéts, I suggested, in the Journal of the Asiatic Society of Bengal, the name of Upper Panchéts for them; but further consideration has induced me to doubt the advisability of expressing a decided opinion upon the subject.

The following is a brief recapitulation in descending order of the various beds above-mentioned, with their divisions, together with the thickness, mostly calculated from their dips, and the dimensions of their out-crops.

Name.	Description of Beds.	Fossils.	Thickness in feet.
I. Upper Panchét (? *Rájmahál group*)	Coarse sandstones and conglomerates ...	Unfossiliferous ...	500
II. PANCHET GROUP	Coarse sandstones, very false-bedded, and red clays. At the base greenish and grey shales and fine sandstones ...	Several ferns distinct from Damúda forms, *Tæniopteris* Sphenopteris. *Schizoneura*—Reptilian and fish remains—*Æstheria* (*Posidonia*). ...	1,500
III. DAMUDA GROUP.			
a. Ŕániganj series	Coarse and fine sandstones, mostly false-bedded and felspathic—shales—coal seams. The latter frequently continuous over considerable areas ...	*Vertebraria*, *Trizygia*, *Glossopteris*, *Pecopteris*, *Schizoneura*, *Phyllotheca*, &c.: all plants.	5,000
*a**. Ironstone shales	Black carbonaceous shales, with numerous bands of clay ironstone ...	Fossils abundant, though not well preserved. *Glossopteris*, &c. ...	1,400
b. Lower Damúdas	Coarse conglomerates, with white sandstones, numerous coal seams of very irregular character, thinning out at short distances ...	*Glossopteris*, *Vertebraria*, *Zeugophyllites ?* &c. ...	2,000
IV. TALCHIR GROUP ...	Coarse sandstone, white, or with a bluish-green tint at top, fine greenish-grey mud, silt, sandy shales, and fine sandstone containing undecomposed felspar; at base rolled masses of great size, 15 feet in diameter, occur in fine silty beds ...	Very rare, a few stems, seeds ? &c. ...	800
	Total ...	...	11,200

In describing these beds in detail, it will be more convenient to treat of them in ascending order, that is, to commence with the Talchir group.

Chapter III.—*The Talchir Group.*

Except in the East of the area, or where cut out by faults, the lowest beds resting upon the metamorphic rocks along the Northern boundary of the Ránigauj field, are the green, grey, and purplish-red muddy and silty beds, which, recognized as identical by their singular mineral character, form the base, in places, of several of the Indian coal fields. Their peculiarities attracted the attention of Mr. Williams, and they have, since 1856, been considered as a group distinct from the over-lying Damúda rocks.

The best sections of the Talchir beds in the Ránigauj field are: 1*st*, North of Panra and Nirsha; 2*nd*, North of Táldánga, near the right bank of the Barákar; 3*rd*, North of Samdi, and in the stream which flows to the East of Jámiari and Baghrám. The lower beds alone are seen in the latter case.

The greatest thickness perhaps occurs North of Táldánga. The section there is well seen over a considerable area of ground, broken and cut up by ravines, in the neighborhood of the village of Railyádi. At the top the beds appear to pass into those belonging to the Lower Damúda. This is the only locality in which such a passage occurs, and there can be no doubt that, at this spot, the interval between the periods of formation of the Talchirs and Damúdas was not one of erosion, and that when the latter group began to be deposited, the sources whence its constituents were derived were identical with those which had previously contributed to the formation of the Talchir beds. The rocks seen near Railyádi form the lowest portion of the measured section given by Mr. Williams at page 73 of his Report, and they were referred to in the Report on the Talchir coal field* as being, probably, from the description of their mineral character and from

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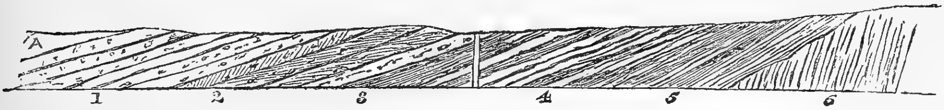
**Memoirs of Geological Survey of India,* Vol. I., page 78.

their position in the series, representatives of the Talchir group, a surmise which has proved correct. The section is

FIG. 1. DIAGRAM SECTION OF THE TALCHIR ROCKS, NORTH OF TALDANGA.



(Descending.)

A. *Damúda Rocks.*

	Feet.
1. Coarse, purple and brown sandstones, with occasional thin interstratifications of fine silty beds. The coarse beds contain numerous pebbles and boulders, mainly of quartzites, and varying in diameter from about 12 inches downwards	165
2. Similar, but less coarse bed of whitish sandstone, weathering with a botryoidal or rather reniform surface. This is in places of a peculiar bluish-green or greenish-grey. These beds become gradually finer in texture towards the base. They are false-bedded	280
3. Thin sandstones and some mudstones, with calcareous nodules ...	50
Trap dyke.	
4. Sandstones interstratified with mudstones—the latter predominating towards the base...	245
5. Fine mudstone, with some bands, irregularly interspersed, of fine hard calcareous sandstone	75
Total ...	815

6. *Gneiss.*

Mr. Williams's section gives 675 feet, but it was probably measured a little further West, where some of the uppermost beds may be denuded. In either case only an approximation has, in all probability, been obtained, there being no easily measured section of the beds exposed.

Where the Talchir group is thick and well developed, the above may be considered fairly to represent the section; coarse white or brown felspathic sandstones, occasionally conglomeritic, occur at the top, and from them there is a gradual passage downwards to fine silty beds. But in proceeding either East or West from the place where the above section

was measured, *viz.* the country North of Táldánga, the uppermost beds in the above section entirely disappear. In the extreme West of the field, the total thickness is nearly the same, but the coarse sandstones are, in a great measure, replaced by finer beds, more typical of the group, and the silty "mudstones" are more abundant. The section seen in the stream running from the North into the Pasai, West of Sonbad, shows:—

(Descending.)

1. Hard, fine greenish-grey sandstone, intercalated with softer muddy beds.
2. Fine grey sandstone, with occasional pebbles.
3. Coarse, black shaley sandstones, with bluish, flaggy beds, and hard grey sandstone. These beds form the greater mass of the group.
4. Fine blackish, shaley bed.
5. Hard, grey shales, rippled in places, and silty beds (mudstones).

The hard, greenish-grey sandstones, which become yellowish-brown by weathering, are seen at the surface in numerous places, North and North-west of Panra, and indeed prevail wherever the Talchir beds occur.

Proceeding towards the East, the Talchirs are gradually denuded away above, and, although no striking unconformity is seen between them and the Damúdas, this gradual thinning, caused by the deficiency of their uppermost beds, plainly shows that it exists. This absence might certainly be due to either of two causes, *viz.* to the circumstance of the upper beds never having been deposited, or to their having been removed by denudation and the very gradual and regular diminution in thickness from East to West indicates the possibility of the former; but there are so few places where the boundaries of the rocks can be traced for more than a few yards, that minor irregularities are very difficult of detection. On the other hand, there are sometimes seen small faults in the Talchir rocks, which cannot be traced into the Damúda beds, and the amount of disturbance, as evidenced by high dips and strongly marked jointing

in several directions, must have been greater in the Talchir group than in the Damúda; so it is probable that upheaval, and denudation also, preceded the period of formation of the latter beds.

One of the best general sections in the whole field is that seen in the West branch of the Núnia stream. In the neighborhood of Jamiari the Talchir rocks are cut through and are well seen. Their total thickness cannot be measured however, the section being intersected by a fault. The greater portion of them consists of greenish-grey sandstones of fine texture. The beds seen are

FIG. 2. SKETCH SECTION OF TALCHIR ROCKS NEAR JAMIARI.

(Descending.)

A. *Damúda Rocks.*

1. Mudstones, and hard bands of fine sandstone, one thin bed of hard, grey calcareous shale contains seeds of plants.

2. Coarse brown grits, containing undecomposed gneiss fragments, with some conglomerate bands. (Pebbles of gneiss throughout.)

3. Finer sandstones, greenish-grey and rather muddy.

4. Sandstone, muddy and hard, and flagstone beds.

Fault.

5. (= 2 and 3 ?) Interstratifications of coarse and fine sandstone, greenish-grey, and dark, and light-brown, with occasional conglomeritic bands and hard lumps of shale. Stratification in parts indistinct.

6. (= 4?) Finer sandstone, generally hard, with occasional irregular beds of muddy flagstones, and flaggy sandstone, all becoming finer towards the base.

7. Fine mudstones.

8. Fault-rock, forming the boundary.

9. *Gneiss.*

North of Samdi some good sections are seen, showing, however, only the lower portion of the Talchir group. In a small stream near Pahárpúr the following section occurs:—

FIG. 3. DIAGRAM SECTION OF ROCKS NEAR PAHARPUR.

(Descending.)

A. *Damúda Group.*

White felspathic sandstone, with numerous pebbles.

Talchir Group.

1. Rather coarse shales and shaley sandstones, with hard, yellowish-brown calcareous bands.

2. Finer slate-colored and dark olive-green shales, breaking into nodular fragments.

3. Fine mudstones, dark olive in color, with a few hard calcareous masses. These beds split up into extremely fine and thin angular splinters, which in places cover the surface of the earth. They are also very much jointed.

4. "Boulder bed," masses of gneiss, of diameters from 1 foot downwards, and numerous small pebbles in a fine calcareous sandstone. This is only a few feet thick.

Gneiss.

The thickness of the above is only 320 feet, being 500 feet less than the section near Mira, North of Táldánga.

The Talchir rocks are cut out by faults in places between Jamiari and the Barákar, East of Jamiari; they continue steadily to Bhádang and Kenjia, where the boundary is thrown to the Northward for several miles by the Alipúr faults. Thence to the East the North boundary is formed by a fault, which cuts out the Talchir beds North of

Panúri. They do not re-appear further East: North of the Adjai, near Kásta, Afzalpúr, and Raswán, a natural boundary extends for about 12 miles, and along the whole of this distance the Damúda series rests directly upon the gneiss, as was observed by Mr. Williams, so that the Talchir beds are completely over-lapped.

Two or three small patches of Talchir beds are brought in by the faults forming the South-west boundary of the field. None of these small areas present any features of interest.

Boulder-bed.

None of the sections above given illustrates the most singular peculiarity of the Talchir group, *viz.* the presence, so frequently referred to, of enormous boulders of gneiss and other metamorphic rocks, in a matrix of the singularly fine silty deposit referred to as mudstone. This boulder bed is not very widely distributed in the Ràniganj field, although boulders, here as elsewhere, occasionally occur in the Talchir beds, especially towards the bottom. The best development observed is seen North of Panra, in the West of the field, and especially in the neighborhood of the village of Chárgora. Here the mudstones are purple and greenish-grey in color, and break up, at the surface, into extremely thin angular fragments, an inch or less in breadth, and from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in thickness, with conchoidal surfaces above and below. The only substance with which it can be compared is fine river silt. Some of the beds are a little coarser, and occasionally thin bands of sandstone occur and form regular interstratifications with the mudstone. Throughout these beds pebbles of all sizes and huge boulders are scattered, the small pebbles being frequently few in number compared to the large ones and boulders. Two boulders, which lay partly broken, were measured; when perfect, they must each have exceeded 15 feet in their longest diameter, and have weighed not less than 30 tons.

All the "*boulders*" are *completely rolled* and *rounded.* The majority consist of varieties of metamorphic rocks common in the neighborhood

of the places where they occur. But a few are occasionally met with, composed of an altered and hardened sandstone, very distinct from any bed now occurring in the immediate vicinity, and apparently even less altered than the sandstones of the Karakpúr Hills, near Monghyr. In one instance, near Chargora, a boulder of clay slate, containing pyrites, was met with. Greenstone pebbles are also found. But the largest pebbles are always composed of gneissic rocks, and those of sandstone, &c., are always rare.

The surface of the metamorphic rocks, upon which the base of the Talchir group rests, is extremely uneven. Its great irregularity is well seen along the North boundary, West of the Barákar, where small hills of it, in some places, as at Madanpúr, stand up through the Talchirs surrounding them. Another instance is seen at Kenjia, North-east of Samdi. In one of the preceding sections, page 37, a hard, green, calcareous conglomerate or boulder bed is mentioned. This appears to plaster over the hollows of the metamorphic rocks in places, and may be the remains of a formation of older age than the Talchirs.

Fossils in Talchirs.

Within the Damúda area, the only fossils obtained from the Talchir group have been a few seed vessels and indistinct carbonaceous markings, probably of stems. These occurred at a spot in the West branch of the Núnia, close to the villages of Gopalpúr and Alkúsa. In one of the small patches of Talchir beds which dot the country North of the Ráníganj field, that on which the village of Karaon stands, a few ferns were found in a calcareous concretion. The best marked was a form intermediate between *Glossopteris* and *Cyclopteris*. Only one or two impressions were found altogether.

In many places, about the middle of the Talchirs, the flags and shales, which are frequently rippled, are covered with irregular pitted impressions, so much resembling foot-prints, that it is difficult to avoid

believing them to be such. But, although frequently searched, no impressions have been found sufficiently definite to prove their origin. They are well seen on the left bank of the Barákar, above Rámnagar, Mr. Hislop has noticed the occurrence of similar doubtful marks in Nágpur upon beds probably corresponding to the Talchir.*

CHAPTER IV.—*Damúda Group.*

Great importance.

RESTING upon the Talchir rocks on the West, and upon the metamorphic rocks in the East, (and, therefore, unconformable in the Ránigan field, as elsewhere, upon the first-named beds,) occurs the most important group of the basin. In thickness, in the area covered, and in economic value, the Damúda group greatly exceeds all the others; to it are confined all the deposits of coal and seams of ironstone, and although fossil remains of greater interest have been found in a higher group, those from the beds now to be described have been longer known, and are far more abundant.

This group of rocks attains a great thickness in the Ránigan field, and it has already been remarked that a distinction exists between the upper and lower portion. In proceeding from the base at the Northern boundary, the first beds met with are coarse, white sandstones, and

Lowest beds.

frequently conglomerates. With these are associated coarse micaceous shaley sandstone, or sandy shale of dark-brown and purple colors, and seams of coal frequently of great thickness, some measuring 30 feet in thickness or even more. These seams are irregular both in thickness and quality; they frequently disappear entirely, or pass into shale or even sandstone within

* *Quart. Jour., Geol. Soc.,* London, Vol. XI., page 371.

short distances. There are seldom very thick beds of sandstone; thin bands, coarse or fine, but more frequently the former, succeed each other at short distances. Many bands are very regular, and have a considerable horizontal extent; very little false bedding is observable. Occasionally poor micaceous runs of ironstone are found, but the most characteristic beds of the formation are the white felspathic sandstones and conglomerates, and the thick beds of coal.

After passing over about 2,000 feet of these rocks in ascending order, a very different class of beds is met with. These are very fine black carbonaceous shales, with numerous runs of clay ironstone (argillaceous carbonate of iron), the latter varying in thickness from about 2 feet downwards. A few beds of sandstone occur especially towards the base of the shales. The soil over-lying these beds is usually strewn with fragments of ironstone, now red from the peroxidation of the iron. No coal has been found associated with this section of the Damúda group.

Ironstones and shales.

These shales, with ironstones, are about 1,200 to 1,500 feet thick, and again are over-laid by sandstones, shales, and coal. But the sandstones are generally finer in texture, and are massed in beds of greater thickness, than those below the ironstones; the coarse, white felspathic sandstone, and conglomerates are almost entirely wanting. Nodular hard calcareous bands are frequent; the coal is more regular, of more even quality, and not so frequently a mixture of coal and shale, and the seams have a uniform thickness over considerable areas. Pebbles are scarcely ever seen, shales are common.

Upper beds.

Conformity.

The questions which arise under these circumstances are, whether between the upper and lower series there is any well-marked distinction either in conformity or in fossil contents, indicating a break? and whether such a break, if it exist, occurs both above and below the ironstone shales, or only in one

of those places? and also how far the different sub-divisions are represented elsewhere.

The unconformity, if it exists, is evidently of small amount, for the general strike and dip of the three series is the same. But this is also the case with the Talchir beds which have been shown to underlie the Damúda rocks so unconformably as to be probably over-lapped to the extent of 500 feet, within a distance of less than 10 miles.

Upper beds conformable on ironstones.

No clear evidence of the unconformity of the upper series of sandstones and coals upon the ironstone shales has been met with. The same strata appear to be in contact throughout, the uppermost bed of the ironstone measures being a somewhat sandy, black shale, and the lowest of the upper series being thin bedded sandstones, with nodular hard bands. It is true that these may both belong to the upper series, but the lower of them appears to pass down into the ordinary carbonaceous shale of the ironstone series. It is, however, difficult in a bed in which sections showing the dip accurately are as rare as they are in the carbonaceous shales, to decide this point.

Ironstones unconformable on lower beds.

But at the base of the ironstones there is better evidence of unconformity. At the first glance at the map it would almost appear as if a great over-lap of the lower Damúda group took place towards the East, the area occupied by them being so much broader to the West of the Barákar. They may perhaps thicken somewhat to the Westward, but if so, the increase is due to the greater vertical development of the rocks composing them, and not to their being overlapped to the East, nor to their having been denuded to any great extent before the deposition of the iron shales. Mainly, however, the appearance is due to the higher dips to the East, and to the lower beds being cut out by faults along the boundary.

Still some denudation does appear to have taken place. Local unconformity is seen at Bágonia, where the Grand Trunk Road crosses the Barákar River. Close to the old Jain temples, North of the Road, both rocks are seen dipping

Local unconformity.

FIG. 4. SECTION OF ROCKS NEAR JAIN TEMPLES OF BAGONIA.

a. Lower Damúda bed. *b*. Ironstone shales.

South by East, at an angle about 10°, but just North of the boundary the dip rolls over sharply to the North for a few yards, and instead of the ironstones being brought in again as they would be, if strictly conformable, the sandstones of the Lower Damúdas are overlaid by beds similar to themselves.

The boundary between the ironstone shales and Lower Damúdas South of the Damúda River, and on the extreme South-west of the field, is very peculiar, but unquestionably indicative of unconformity. The runs of conglomeritic sandstone of the lower series form little ridge-like elevations, 20 or 30 feet high, and on following some of these along their strike, they are found to be cut off without a fault, and to abut abruptly against ironstones with the same dip and strike. In one case one of these is far prolonged into the ironstones being interstratified between them, and narrowing gradually from about 50 yards in breadth. To the South the ironstones thin out completely; their lower beds being over-lapped by the higher ones. Nowhere South of the fault, which crosses from North-west to South-east by Chánch and Núchibád, are they more than a few hundred feet thick. The upper series rests throughout regularly upon them.

It is probable, that in this place were the shores of the original basin of deposit of the ironstone shales, those shales having been formed of denuded but horizontal beds of the Damúda group. Hence the perfect

conformity in dip. The run of conglomeritic sandstone extending into the ironstone shales is most anomalous and difficult to account for, the only explanation which appears probable is, that it may have been a beach deposit, formed from the Lower Damúdas, and thus resembling them so closely as to be undistinguishable when consolidated. A sharp change in the direction of the strike, which occurs just where ironstone shales come in beneath the conglomerate bed, supports this probability.

Old shores of basin.

It is also possible, as the ironstone shales are evidently much thinner South of the Chánch fault than they are to the North, that that fault was partly formed at a period subsequent to the age of the Lower Damúda group and antecedent to that of the ironstone shales, and that disturbance and denudation of the former took place prior to the formation of the latter.

Altogether there seems to be little reason to doubt that a slight break of continuity exists between the Lower Damúdas and the ironstone shales. But no evidence of a similar break has been observed on the top of the ironstones. It may exist: careful search, however, has failed to prove its presence, and the tendency of the evidence at present is to show that the ironstone shales are the lowest portion of the upper series.

So few good fossils have been obtained from the Lower Damúda group, in comparison with the large collections obtained from the upper series, that the merely negative characters exhibited cannot be considered to have any great weight in confirming the value of the two divisions. Fossils are not rare in the ironstone shales, though badly preserved. But, although good specimens of fossil plants are, in consequence of the sandy nature of the beds, less frequently obtained from the Lower Damúda, the impressions themselves are quite as abundant, and as generally scattered as in the Upper series. The latter alone have furnished in the Damúda field forms of *Pecopteris*, *Trizygia*, and a plant

Comparison of fossils.

allied to *Schizoneura*. The two first-named genera are very rare, but the last is so abundant and so generally distributed, that the circumstance of its not having been discovered in the lower series is very probably due to its absence, while leaves of a similar or closely allied plant (*Zeugophyllites*) have been found in the lower, but not in the upper series. *Vertebraria, Glossopteris* of several species (more in the higher than in the lower beds), *Phyllotheca*, and other plant remains abound throughout.

Representations of Damúda rocks elsewhere.

There being thus, both on physical grounds and on fossil evidence, a probability of a division in the Damúda group of the Ràniganj field, it remains to be seen which portion represents the group as described elsewhere, for as yet there has, in no other area, been found evidence of a distinction.

Rájmahál Hills.

The districts in which Damúda rocks occur, and of which the writer can speak from personal experience, are the Rájmahál Hills and the Talchir basin. In the former case, and, probably, in the latter, the representatives of the beds of the Ránigani field are confined to the Lower Damúda group, to which the mineral character of the beds closely approximates. In the case of the Rájmahál Hills this is so marked as to be sufficient evidence, but the Talchir field is too far away for certainty. In the former instance, and to some extent in the latter, no such beds of rather fine felspathic sandstone false-bedded and of great thickness are found as occur in the upper series of Ránigani. Sandy micaceous shales, poor gritty ironstones, white and grey conglomeritic sandstone, all of which, if abundant, characterize the lower division, are abundant, and the coal seams are of inferior quality and irregular thickness. Of the Lower Damúdas

Narbadda.

of the Narbadda it is more difficult to speak with certainty; the description of their mineral character would apply equally to either division, and, indeed, at so great a distance, mineral character must be unusually marked and peculiar in

order to have any value. But in this instance, as in every other, the non-discovery of either of the species of *Schizoneura*-like plant, one of which is so abundant in the Upper series of the Rániganj field, is strong evidence in favor of the opinion that no representatives of the Upper series have yet been examined beyond the area now under consideration.*

Jariagarh.

A field of Damúda rocks exists near Jariagarh, about 15 or 20 miles West of the Rániganj field. It has not been visited by the present survey; but it is stated that it contains ironstones with carbonaceous shales. It is difficult to say if these represent, in any way, the great band of the Rániganj field, as numerous similar deposits of small extent and thickness occur, both in the higher and lower series of the Damúda group. The circumstance that Mr. David Smith† considered the deposit at Jaria as unimportant, renders it probable that it is merely a thin local bed. We have therefore no evidence as to the presence of the Rániganj series at Jaria.

Ramghur.

Mr. Williams distinctly states that both the ironstone shales and the upper series occur in the Ramghur coal fields, South of Hazáribágh.‡ The only information concerning these fields, however, is contained in this Report, based on the imperfect notes found after Mr. Williams's death, which took place while he was engaged in the examination of those districts. The remarks on the subject are extremely confused, but if they imply, as they appear to do, that the few bands of ironstone detailed in the section, at pages 49 to 52, represent the great band of ironstones of the Rániganj field, the evidence offered appears scarcely sufficient to warrant such an opinion. It is also worthy of notice, that conglomerates, the absence of which is

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* It must be remembered that the collections of fossils obtained from the Narbadda Valley are as yet exceedingly small and imperfect.—T. OLDHAM.

† *Report on the Coal and Iron Districts of Bengal*, page 9. 1856.

‡ *Geological Reports on the Kymore Mountains, Ramgurh Coal Fields, &c.* Calcutta. 1852. Pages 27, 43, 44, and 53.

one of the chief peculiarities of the Upper series in the Ŕániganj field, form the highest beds of the section.

From all these facts, whether the upper series be represented elsewhere or not, there can be little doubt that the term Lower Damúda must be restricted to that portion of the group in the Ŕániganj field which underlies the ironstone shales, and which, doubtless, represents a portion of, if not all, the Damúda rocks of other areas. For the Upper series, as already mentioned, the name of Ŕániganj series is proposed.

CHAPTER IV., SECTION 2.—*Lower Damúda Group.*

THE principal general characteristics of this series having been described above, it only remains to mention the local forms which it assumes, and the places where coal is known to exist within its area. Commencing for this purpose in the North-east of the field, we find two long strips of sandstone, both belonging to this portion of the Damúda group, lying North of the River Adjai, and in the district of Beerbhoom. The more Eastwardly of these lies North of the Hingla stream; it is about 6 miles in length, and nowhere more than a mile in breadth, being bounded on the South by a fault, which brings up metamorphic rocks. It only contains sandstones and sandy shales, and no coal is known to occur.

North of River Adjai.

The other small area is more interesting. It extends from Hazratpúr on the East, to beyond Kásta, a distance of about 13 miles. To the North it rests naturally on the gneiss for the greater portion of the distance, but it appears to be let in by faults about Kásta. It is very narrow, being covered up to the South by the alluvium of the Adjai as far as a little West of Afzalpúr; beyond that, a large fault,

running down the bed of the Adjai, forms its Southern boundary, and causes the metamorphic rocks to be brought up South of the river.

Boring at Raswán.

All the Western portion of this small area, until the rocks are covered by alluvium, consists of coarse sandstone. This is fairly exposed about Raswán, just East of which a boring was made by the East India Coal Company, in consequence of some carbonaceous shale being found in the village. As might have been expected, no coal was found, and at a depth of 95 feet the borer came upon the hard gneiss rock.

Quartz seen at Bara.

Just at the North end of Bara Village, a vein of quartz is seen apparently cutting through the Damúda beds and altering them. It so resembles granitic veins, that it is difficult to avoid believing that it is one. However, it may be aqueous in origin, as it is by no means well seen.

Near to this, conglomerate bands occur near the boundary, which is much faulted between Bara and Afzalpúr. Some carbonaceous shales, and, it is said, coal, were found in digging a well 15 or 20 feet deep at Afzalpúr, but the thickness is not known.

Coal at Khorabád.

Near Khorabád a quarry was opened in a seam of very inferior coal, by Mr. Nicol. It has now been abandoned for many years, and, being of course full of water, all that can be seen is a thin seam of carbonaceous shale. The coal seam was of but small thickness. Further West, in the Sadarangi stream, about $1\frac{1}{2}$ miles East of Kásta, the rocks seen at the base of the Damúdas are coarse, white, felspathic sandstones, upon which come purple and brown shales and a small seam of coal, about 1 foot thick, then two or three little runs of ironstone of good quality, with shales.

Coal at Kásta.

The only coal seam worked, or that is known to be worth working, in this strip of measures, is at Kásta. Here two collieries exist, one, now the property of the East India Coal Company, the other belonging to Messrs. Nicol and Sage.

The rocks near the quarries dip at a high angle (30°), and consist of hard sandstones and shaley flags. The section of the seam in Messrs. Nicol and Sage's quarries is

				Ft.	*in.*
1.	Thin, shaley, false-bedded sandstone, pink in color, coarse and felspathic			14	0
2.	Coarser sandstone, white and felspathic			1	6
3.	Thin sandstone similar to No. 1			1	6
4.	Carbonaceous shale			1	0
5.	Coarse sandstone			0	2
6.	Carbonaceous shale			1	6
7.	*a.* *Coal*, very bright in parts	7	0		
	b. Carbonaceous shale	1	6		
	c. *Coal*, with irregular partings of shale, quality somewhat shaley and inferior	14	0		
	d. Shale	0	2		
	e. *Coal* of good quality, but variable	11	6		
				34	2
8.	Carbonaceous shale				

The quarry of the East India Coal Company is not 100 yards off, but in it the coal is 2 feet thicker: some of the partings disappear, and the section roughly is

	Ft.	*in.*
Coal, shaley and inferior...	7	6
Carbonaceous shale	1	6
Coal, poor above, good below	27	0
Total	36	0

The seam cannot be traced here in either direction, and despite its immense thickness, probably thins out at no great distance. It is even possible that it may be represented by the thin strings of coal already mentioned, on the Sadarangi stream and near Khorabád.

In this seam, the lower 11 feet are by far the finest portion, and although variable, as are all the seams of the Lower Damúdas, it contains in places excellent coal. It has been worked away in large galleries close to the out-crop. From the distance of this seam from

the Damúda, and from the railway, it can scarcely be worked at a profit, but in the years 1858-59, owing to the great demand for coal for the East India Railway, between the Adjai and the More, large quantities, even of the inferior portions of the Kásta seam, were quarried, and carried in carts to Sainthia and Súrúl (Soorool).

The tract of alluvium North of the Adjai, and South of the villages of Afzalpúr, Bara, Raswán, Hazratpúr, &c., is, doubtless, under-laid by rocks of the Lower Damúda series; and borings near Parsúndhi, Támra, Samúldhi, and Binanpúr, may show the presence of coal seams. About Séria (or Sira), Jamalpár, and Lobasán, it is very possible that ironstone shales may occur, or they may extend even farther to the North. But their position can only be conjectured.

Rocks South of Adjai.

South of the Adjai, the area occupied by the Lower Damúda group is considerable, and it increases gradually to the Westward towards the Barákar. West of that river, nearly the whole area is occupied by these rocks. In describing this large tract of coal-bearing rocks, it will be most convenient to speak of the various localities in succession, commencing with the most Eastwardly.

Fault in River Adjai.

Lower Damúda rocks first appear South of the River Adjai, close to Darbatdánga, a little East of Birkúnti. The great fault, with a down-throw to the North-east, which has been already mentioned as passing down the river and bringing in the Kásta beds, to the East of Darbatdánga, passes across the Lower Damúda rocks, cutting out all beds below the ironstone shales; but the immediate neighborhood of the river here is occupied by alluvium. In the bed of the Adjai, close to the place where the Nánlin Jor, a small stream from the South, falls into the river, the sandstones are much infiltrated with carbonate of lime, and are covered in places with a tufaceous deposit. The quantity of carbonate of lime is, however, small, and it is worthless for economic purposes.

Tufaceous deposits.

West of Birkúnti, in the neighborhood of Jainagar and Churalia, the Lower Damúdas are fairly seen. Metamorphic rocks come in South of the Adjai fault, but the North boundary of the field being here also a fault, the whole thickness of the lower series is not exposed. The beds consist of grits and coarse felspathic sandstones below, and, near the top, of sandy shales, coarse and fine ferruginous sandstones, micaceous sandstone, and occasionally coal. The highest beds beneath the ironstones are very thin micaceous shales, sometimes containing black band, as is well seen near Darbatdánga. Below these some ordinary ironstone shales are seen, and there is an appearance, in this part of the field, of a passage from the Lower Damúda group into the ironstone shales, just as North of Táldánga there is an apparent passage from the Talchir into the Damúda series.

Coal near Jainagar.

These rocks stretch across the high ground between several small streams running North to the Adjai. At Jainagar a quarry was once opened by a native,* in a seam said to be 7 or 8 feet thick, and of good quality, but no reliance can be placed upon the information. The out-crop of the seam is seen for some distance in the neighborhood of a trap dyke, which, in all probability, throws off small irregular intrusions into the coal, and injures it.

And Churalia.

In the small stream due North of Churalia, three out-crops of coal are seen: of these, the lowest bed, near the boundary of the metamorphic rocks, may be 8 or 10 feet thick, and the out-crop can be traced for 2 or 300 yards to the West, close to the boundary. This seam is perhaps identical with that seen near Jainagar. The higher seams cannot exceed 3 or 4 feet in thickness. They lie just above the thicker one, but all are extremely ill seen.

* It is frequently most difficult to ascertain by whom the numerous small quarries scattered over the country were worked.

No coal is known to occur West of this for a considerable distance, the beds from Madanpúr to Etiapúra on the Núnia, being very similar to those seen from Birkúnti to Churalia. Coal may, however, very probably be found throughout this area, if a proper system of exploration by borings or small sinkings be adopted. West of Panúria, and just South of a small village called Digalpahári, there is an out-crop of what appears to be a burnt seam of coal.

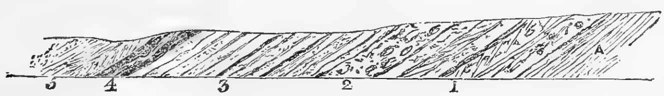
Near Panúria.

East of Alipúr and Etiapúra, a great fault, with a down-throw to the North-east, completely cuts off the fault, which has so far formed the North boundary of the field. West of this, (and for a short distance East of it,) the Talchir rocks come in, and the whole thickness of the Lower Damúda group crops out. No good sections through them, however, are seen for a considerable distance. In the Núnia, just North of Etiapúra, two out-crops of coal are seen, and two, or perhaps three, more near Alipúr. All, however, here dip at high angles, and are doubtless broken from the proximity of the North-west and South-east faults.

The lower beds of the Lower Damúda group are well exposed from Etiapúra to Samdi, in the numerous ravines and broken ground in the neighborhood of the Núnia. The following section, in continuation of that given previously from the Talchir series, (see Fig. 3, page 36,) North of Samdi, illustrates well the character of the beds.

North of Samdi.

FIG. 5. SKETCH SECTION OF THE LOWER DAMUDA ROCKS NEAR SAMDI.



(Ascending.)

A. *Talchir rocks.*

1. White felspathic false-bedded grits and sandstone, conglomeritic in places.

2. Coarse conglomerate of quartz pebbles, in white felspathic sand.

3. Sandstone, with two thin irregular seams of *coal.*

4. Thick seam of *coal* (exact thickness not seen) containing intrusive trap.

5. Coarse, false-bedded brown grits.

No carbonaceous shales are seen to occur—just here coal, and white or grey sandstone being the principal beds. A thick seam of coal extends in the neighborhood of the Núnia, from near Etiapúra to Samdi. The out-crop is seen for a considerable distance North-east of the last-named village. It is extremely irregular, nor is it indeed certain that it can be considered as one continuous seam, for it frequently splits up into three or four, and the partings generally are masses of sandstone of extreme irregularity in thickness and appearance. This irregularity, as will be seen, is characteristic of all the seams of coal in the Lower Damúda group.

Thick seam in Núnia.

Just where the Sálma dyke crosses the Núnia, this coal seam is seen to be of enormous thickness, perhaps as much as 70 or 80 feet. But of this the greater portion is utterly worthless, being merely a mixture of coal, shale, and sandstone, and it may be doubted whether any portion would repay extraction. Still it is well worthy of exploration, as portions of the seam or seams may be found to supply excellent fuel. A native has cut into the out-crop near Amdia, but the coal abounds in pyrites, and is of very inferior quality.

Grits at base of Damúda series.

The thick bed of white felspathic grit forms the base of the Damúda series for a great distance to the West, and is found beyond the Barákar. It is distinguished from somewhat similar beds in the Talchir group, by being somewhat coarser and more decomposed, and by never, so far as observed, having the bluish-green tinge so generally seen in the coarser sandstones of the Talchir group.

Above these lowest beds comes a series of grits and shales, intersected in every direction by traps, and so much hardened by them, that they form a raised ridge, on which stand the villages of Etiapúra, Amdia, Pahárgora, Saṁdi, Nauháth, &c. No coal is seen to occur in these beds, and if any exist, it is, doubtless, too much hardened and injured by trap to be workable. Some coal, however, is seen immediately beneath. South of the ridge there are no sections of the Lower Damúda rocks.

Trap intrusions near Samdi.

These beds are tolerably exposed in the West branch of the Núnia. The upper part of the section is not well seen, but some are cut through towards the base.

West branch of Núnia.

The following beds are seen in descending order:—

1. Sandy shale and sandstone of purplish-red and brown colors, somewhat micaceous, and containing a few runs of ironstone.

2. Coarse micaceous carbonaceous shale, with fossil plants.

3. Coarse, dark-brown ferruginous sandstone, in beds of moderate thickness, with some carbonaceous shale.

4. Shale, with bands of hard grits.

5. Black carbonaceous shale, with seams of sandy and impure ironstone.

6. Coarse, black shale, with imperfect plant remains.

7. Hard massive bands of slightly ferruginous quartzose grits at intervals. Intermediate beds not exposed.

8. Reddish and yellowish sandstone.

9. Massive, coarse, grey and yellow sandstone, with peculiarly jointed (tesselated) ferruginous bands. Some beds of carbonaceous sandy shale, with imperfect plant remains.

10. *Coal,* about 2 feet thick, resting on about 3 inches of ferruginous sandstone.

11. Sandstone, hardened by trap.

12. Coarse carbonaceous and ferruginous sandstone, false-bedded, and in places passing into shale.

13. Coarse brown grits, with little pieces of quartz, only imperfectly rounded.

14. Carbonaceous shale.

15. *Coal*, thickness not seen, but apparently considerable, about ... ... 15 feet.

The lower part of the seam contains trap.

16. *Coal* and carbonaceous grit, with trap, about ... 20 „

17. Light-brown sandstone, with some pebbles, and a few shaley beds interstratified, about ... 10 „

18. Trap ... ... 2 „

19. Black carbonaceous shales and sandstone ... 10 „

20. Conglomerate, quartz pebbles in white felspathic grits and sandstones ... ... 60 „

21.	Black carbonaceous shale ...	6	13 „	
	Sandstone	2		
	Black carbonaceous shale ...	5		

22. White felspathic sandstone, with pieces of quartz and felspar, and a few hard bands.

The only coal seam worthy of notice is No. 5, 12 or 14 feet thick, which is seen between Alkúsa and Gopalpúr. Like most of the seams in this neighborhood, it is much cut up and hardened by trap. A smaller and thinner seam underlies it.

Measured section near Lálbazár.

West of the Núnia and North of Lachmanpúr, Lálbazár, &c., the beds are much twisted and faulted, and are still full of trap dykes, which, indeed, occur more or less abundantly throughout the Lower Damúda rocks, and almost always send out ramifications into the coal seams. The lower beds here are similar to those already described as occurring North of Samdi: the higher beds are well seen just North of Lálbazár,

and are best exemplified by the following measured section of Mr. Williams.*

	Ft.	in.
1. Black and gray argillaceous shales, containing iron-mine (seen)	40	0
2. Gray and brown sandstone	40	0
3. Inferior *coal* (seen)	1	0
4. Gray underclay, with arenaceous nodules	2	0
5. Light-gray sandstone, coarse-grained, quartzose, felspathic, and micaceous	32	0
6. Argillo-arenaceous shales, with stains of carbonaceous matter ...	4	0
7. Brown sandstone	0	8
8. Argillo-arenaceous shale	6	6
9. Brown sandstone with ripple-marks	12	6
10. Inferior *coal*	2	0
11. Gray argillo-arenaceous underbed	10	0
12. Brown sandstone, coarse-grained, felspathic, and quartzose ...	56	0
13. Arenaceous shale	20	0
14. Black argillaceous shale	5	0
15. Dark-brown sandstone, micaceous, and alternating with arenaceous shale	27	0
16. Black argillaceous shale	5	0
17. Thin-bedded sandstone, alternating with arenaceous shale ...	23	0
18. Brown sandstone, quartzose, felspathic, coarse-grained, and hard	13	0
19. Arenaceous shale	10	0
20. Brown sandstone, containing concretions of arenaceous limestone	21	0
21. Hard sandstone, white and light-gray, occasionally stained red and brown	21	0
22. Brown sandstone, quartzose, felspathic, and hard	19	0
23. *Coal*, seen on out-crop	1	0
24. Gray under-bed	3	0
25. Brown and light-gray sandstone, thin and regularly bedded, and containing rounded boulders of quartz six inches diameter	18	0
26. Thick-bedded sandstone, containing large grains of quartz ...	30	0
*27. Brown arenaceous limestone in large concretions	2	0
28. Argillo-arenaceous shale	18	0
29. Gray arenaceous shale	24	0
30. Arenaceous ironstone	0	2
Carried over ...	466	10

* Geological Report on the Damoodah Valley—pages 84—87.

	Brought forward ...	466	10
31.	Argillo-arenaceous shale	3	0
32.	Arenaceous ironstone	0	2
33.	Argillo-arenaceous shale	9	0
34.	Brown sandstone	0	3
35.	Dark-gray argillo-arenaceous shale	4	0
*36.	Argillaceous limestone concretions	0	6
37.	Black and gray argillaceous shale	9	0
*38.	Argillaceous limestone concretions	0	6
39.	Argillo-arenaceous shale	6	0
40.	Hard arenaceous shale	0	3
41.	Dark-blue argillo-arenaceous shale	6	0
42.	Argillo-arenaceous shale	15	0
43.	Arenaceous ironstone	0	4
44.	Dark-gray argillo-arenaceous shale	7	0
45.	Brown sandstone	0	5
46.	Argillo-arenaceous shale	2	0
47.	Arenaceous shale	0	8
48.	Dark-gray argillo-arenaceous shale	4	6
*49.	Argillaceous limestone in two beds	1	0
50.	Gray argillaceous shale	1	0
51.	Dark-gray arenaceous shale	12	0
52.	Brown sandstone	1	0
53.	Arenaceous shale	4	0
*54.	Yellowish-brown argillaceous limestone	1	0
55.	Gray argillo-arenaceous shale	4	0
56.	Light-gray conglomerate	2	0
57.	Gray argillaceous shale	1	6
58.	Yellowish-brown arenaceous limestone (nodular)	0	6
59.	Arenaceous shale, with partings of a red color	4	0
60.	Light-gray sandstone, coarse-grained, quartzose, felspathic, and micaceous	4	0
61.	Argillo-arenaceous shale	3	0
*62.	Yellowish-brown argillaceous limestone	0	6
63.	Dark-gray argillo-arenaceous shale	9	0
64.	Hard gray sandstone	0	4
65.	Black argillo-arenaceous shale	15	0
66.	Gray arenaceous shale	1	0
67.	Black argillo-arenaceous shale	5	0
68.	Light-gray conglomerate, with pebbles of white quartz ...	3	0
69.	Brown arenaceous shale	2	0
70.	Light-gray quartzose sandstone	3	0
*71.	Brown and gray limestone	2	0
	Carried over ...	615	3

	Brought forward ...	615	3
72.	Light-gray sandstone, felspathic	2	0
73.	Compact sandstone, quartzose	3	0
74.	Black argillaceous shale	2	0
75.	Brown sandstone	1	0
76.	Inferior *coal*	1	0
77.	Arenaceous under-bed, with fibre-like impressions of plants ...	1	0
78.	Brown sandstone, micaceous	1	6
79.	Light-gray arenaceous shale	3	0
80.	Gray and brown compact sandstone	21	0
81.	Greenish-gray arenaceous shales, lightly stained red	15	0
82.	Black and gray argillo-arenaceous shale, with hard arenaceous bands	30	0
83.	Gray arenaceous shale	15	0
84.	Gray sandstone	25	0
85.	Gray and brown argillaceous shale, micaceous and hard ...	37	0
86.	Brown sandstone	3	0
87.	Gray argillaceous shale	1	0
88.	Brown sandstone	0	4
89.	Dark-gray argillo-arenaceous shale	5	0
90.	Brown sandstone	0	4
91.	Black argillo-arenaceous shale	3	0
92.	Gray and brown arenaceous shale	4	0
93.	Light-brown sandstone	3	0
*94.	Yellowish-brown argillaceous limestone	1	0
95.	Light-gray argillo-arenaceous shale	9	0
96.	Brown sandstone	9	0
97.	Yellow and brown sandstone	3	0
98.	Argillo-arenaceous shale	4	0
99.	Black argillaceous shale	0	6
100.	Light-gray sandstone	0	6
101.	Black, gray, and brown arenaceous shale	0	9
102.	Inferior shaley *coal*	7	0
103.	Hard sandstone	1	0
104.	Inferior *coal*	3	0
105.	Gray arenaceous shaley under-bed...	6	0
106.	Sandstone, quartzose, and hard, passing into conglomerates.		
	Total	837	2

The above section, giving altogether a thickness of 837 feet, which are well seen in the streams and ravines North of the village of Lálbazár, entirely overlies the representatives of the beds seen North

of Samdi. The measures detailed are destitute of workable coal. In the lower portion of the Lower Damúdas several seams occur. One said to be about 10 feet thick is seen South of Dendwa and East of Lakrajori, dipping sharply toward the fault which passes there. It was once worked, many years since, by a native.

Coal near Dendwa.

The seam worked by Messrs. Erskine and Co., North of Lálbazár, is altogether 18 feet in thickness, of which 10 feet is extracted. The coal is hardened by trap, by which a proportion of the seam is rendered useless, and it is, as usual, variable in quality. A smaller seam underlies it. A little to the West of the colliery there is a twist in the strike, and the seams are difficult to trace.

Lálbazár.

Another seam is seen just North of Rámnagar, and close to the Barákar, but, like so many others, it is cut up and injured by trap. A second seam, thin and shaley, occurs about half a mile South of Rámnagar. Just North of the Jain temples at Bágonia also, close to the spot where the Grand Trunk Road crosses the Barákar, a bed, the thickness of which is not seen, occurs, and has been irregularly quarried.

And Rámnagar.

West of the Barákar River is an area abounding in coal seams, many of them of enormous size. This tract has been by several persons quoted as the most promising and valuable portion of the Ráníganj field, on account both of the abundance and the excellence of the fuel there found. The abundance has not only been confirmed, but many seams not previously laid down have been mapped by the present Survey. These seams, however, seldom appear continuous over the whole area of the field; they can often not be traced

West of Barákar.

for more than a few hundred yards, and the quality of the coal may (and in general does) vary within even shorter distances. An admirable example is seen in the Kúdia stream, at the bend due South of Nirsha, and near the village of Sampúr. Here a 13 feet seam of coal is seen, within 50 yards, to split into two, and the lower seam to change into sandy shale. 300 yards from the place where it was first seen, a seam apparently identical, but only 7 feet thick, is found; and this is certainly not an extreme case. Many seams of considerable thickness seem to disappear entirely within a shorter distance.

Irregularity of coal seams.

Of course, in a region where no mine of any size exists, it is impossible to say whether there are exceptions to this rule or not. The most extensive workings that have ever been made in the beds of the Lower Damúda group, within the Rániganj field, have never been more than galleries driven in from the out-crop, and these have probably in no case reached for 100 yards in distance, nor to a depth of 50 feet from the surface. The quality of the coal is, in many cases, admirable; the best yet procured in the Damúda field is said to have come from the mines West of the Barákar.* The assertion, however, so frequently made, that coal suitable for coking purposes has been procured from Chánch, Kúmardhúbi, and other places, has never been satisfactorily proved, and is certainly incorrect in the case of Chánch.

Injured by trap.

One circumstance which seriously interferes with the seams of the Lower Damúda group is the frequency with which they are injured by trap dykes. These ramify, for great distances, and in a most peculiar manner, through many of the seams, converting the coal into a hard, dense, shaley substance, apparently an impure authracite, which is frequently most beautifully columnar.

* The coal of Sirsol, Nimcha, and some other seams near Rániganj is probably equal to any yet found West of the Barákar.

Coal near Barmúri.

Immediately West of the Barákar several seams of coal are seen in the neighborhood of the village of Barmúri. The highest in the series are about half a mile South of the village, and consist of two seams seen on the bank of the Barákar, the highest and largest, however, is only 4 feet thick. Immediately South of Barmúri a seam occurs, which has been worked to some extent by natives many years ago; it is an admirable example of an irregular seam, the thickness being any thing between 15 feet and 30, and the seam itself being a mixture of coal, shale, and sandstone, each of which passes into the other, so that some layers of the seam which at one point are coal, 20 yards further may be hard, gritty sandstone, without any carbonaceous appearance. Not many feet beneath this seam, and just North of the village, occurs another seam from 15 to 20 feet thick, which has also been cut into. It is, if possible, even more irregular and inferior in quality than that South of Barmúri. It is also much altered by trap. Thirty or forty feet lower in the section, a third seam is seen, of great thickness, probably nearly 30 feet; a fourth seam occurs about 10 feet below the third, and a fifth a short distance further North; but the out-crops of the latter are not so well exposed. Supposing the two lower seams, each to measure 10 feet, there is, in this spot, a thickness of nearly 100 feet of coal, nearly the whole of which, so far as can be judged from its appearance at the surface, is worthless for anything, except brick and lime burning.

Thickness.

Bad quality.

Seam near Táldánga.

Passing Westwards, many indistinct out-crops are seen near Mira and Táldánga. A fine seam was dug into for 6 or 8 feet, in sinking a well to the depth of about 30 feet at the dâk bungalow. Immediately West of the latter, there runs a stream called the Jhelia, in the banks of which, in places, a

very imperfect section of the beds is seen. The measures seen in the banks of this stream were carefully explored by Mr. Williams, partly by means of pits and borings, and from the combination of these, with other measurements, he gives the following as a general section of the Lower Damúda group in the neighborhood of Táldánga* :—

Mr. Williams's section.

(Descending.)

	Ft.	in.
1. Black and gray argillaceous shale, containing the carburet of iron, or argillaceous ironstone, and bands of sandstone ...	192	0
2. Black and gray argillaceous shale, alternating with bands and beds of sandstone, and containing nodules of ironstone ...	178	0
3. Black argillaceous shale and ironstones in great profusion ...	186	0
4. Indication of *coal* here.		
5. Black and gray argillaceous shale, containing nodules and bands of iron-mine	218	0
6. Black and gray argillaceous shale, alternating with bands and nodules of iron-mine, and also with beds of sandstone ...	219	0
7. Gray and brown conglomerate and sandstones, alternating with thin beds of gray and brown argillo-arenaceous shale, containing nodules of argillo-arenaceous limestone	310	0
8. Brown sandstone conglomerate, very hard and compact ...	12	0
9. Light-gray sandstone, coarse grain, quartzose, felspathic, and partially stained red and brown	20	0
10. Concretionary *coal* (Chaunch seam)	12	0
11. Arenaceous under-bed, with fibre-like impressions of plants ...	4	0
12. Light-gray and brown sandstone conglomerate, with occasional alternations of thin beds of shale	86	0
13. Arenaceous shale, with subordinate beds of sandstone ...	150	0
14. Sandstone and shale	22	0
15. *Coal*, thickness unknown.		
16. Light and dark-gray sandstone and shale, alternating in beds of various thickness	228	0
17. Sandstone, hard and coarse-grained	20	0
18. Thin-bedded sandstone, micaceous and gray	14	0
19. Black bituminous shale	2	0
20. Black siliceous rock, with a conchoidal fracture, and containing flakes of vegetable charcoal	8	0
Carried over ...	1,881	0

* Report on the Damoodah Valley, &c., pages 69 to 74.

Brought forward			...1,881	0
21. *Coal* seen near experimental shaft No. 17, thickness seen on outcrop			6	0
22. Under-bed arenaceous			4	0
23. Sandstone alternating with gray argillo-arenaceous shale ...			60	0
24. Gray and black argillaceous shale			20	0
25. Gray and brown arenaceous shale, occasionally stained red ...			24	0
26. Sandstone, quartzose and hard			20	0
27. Black siliceous rock, with conchoidal fracture, and containing flakes of vegetable charcoal			17	0
28. Black bituminous shale			5	0
29. Black siliceous rock, with conchoidal fracture, and containing flakes of vegetable charcoal, and exceedingly hard			26	0
30. *Coal* inferior in quality	3	0		
31. Black bituminous shale	1	6		
32. *Coal*, superior, found in experimental shaft No. 16 ...	2	2		
			6	8
33. Under-bed			6	0
34. Sandstone			70	0
35. Gray argillaceous shale			6	0
36. Hard sandstone			0	4
37. Argillo-arenaceous shale			3	0
38. Hard rock, fine grain			0	4
39. Argillo-arenaceous shale			3	6
40. Hard rock, fine grain			0	4
41. Argillo-arenaceous shale of a dark-gray color, and a band of rock			8	3
42. Hard sandstone, micaceous, and fine-grained			5	0
43. *Coal* seen near shaft No. 15, thickness not ascertained beyond three feet on the out-crop			3	0
44. Under-bed			5	0
45. Sandstone and argillo-arenaceous shale			40	0
46. Brown sandstone			20	0
47. Arenaceous shale, micaceous			18	0
48. Thin-bedded sandstone			9	0
49. Superior *coal*			0	7
50. Carbonaceous shale			0	10
51. Superior *coal*			0	4
52. Gray arenaceous under-bed, with fibre-like impressions of plants			2	0
53. Brown conglomerate			9	0
54. Superior *coal* found in experimental shaft No. 13			9	0
55. Gray arenaceous under-bed, containing large concretions of arenaceous iron-mine			4	0
Carried over			...2,293	2

	Brought forward	...2,293	2
56.	Light-gray conglomerate sandstone, containing white pebbles of rounded quartz	15	0
57.	Gray argillaceous shale	3	0
58.	Black argillaceous shale	4	0
59.	Superior *coal* found in excavation No. 12	1	4
60.	Gray arenaceous under-bed, containing large concretions of arenaceous ironstone from 3 to 4 feet diameter, and 1 foot thick	5	0
61.	Black and gray argillaceous shale	6	0
62.	Brown sandstone	2	0
63.	Carbonaceous shale	4	0
64.	Light-gray sandstone, quartzose, micaceous, and hard ...	3	0
65.	Hard bright *coal*, found in shaft No. 11	0	8
66.	Gray argillo-arenaceous under-bed	1	4
67.	Gray sandstone	0	4
68.	Black and gray argillaceous shale	0	6
69.	Gray sandstone, fine-grained, micaceous	6	0
70.	Gray and brown sandstone conglomerate	60	0
71.	*Coal*	0	1
72.	Carbonaceous shale	0	8
73.	*Coal*	0	1
74.	Under-bed	0	10
75.	Sandstone, gray and brown, passing into conglomerate near the top	30	0
76.	Argillo-arenaceous shale	9	0
77.	Inferior *coal*	0	7
78.	Sandstone	0	4
79.	*Coal*	0	5
80.	Black argillaceous shale bed	3	0
81.	Brown and gray sandstone conglomerate	162	0
82.	Inferior *coal* in excavation No. 8	10	0
83.	Arenaceous under-bed	4	0
84.	Argillo-arenaceous shale	6	0
85.	Light-gray conglomerate	38	0
86.	*Coal* seen in brook near shaft No. 7	6	0
87.	Gray under-clay	2	0
88.	Slaty *coal*	1	0
89.	Hard bright *coal*	0	6
90.	Gray arenaceous under-bed	6	0
91.	Brown conglomerate	18	0
92.	Light-gray argillaceous shale	7	0
93.	Brown conglomerate	25	0
	Carried over	...2,735	10

	Brought forward	...2,735	10
94.	Inferior *coal*, with metallic fracture	3	0
95.	Hard rock, colored red, alternating with black argillaceous shale	0	9
96.	Gray arenaceous shale	4	0
97.	Grayish-white sandstone conglomerate	120	0
98.	Brown conglomerate	12	0
99.	Black carbonaceous shale	4	0
100.	Gray argillaceous shale	3	3
101.	Red sandstone	0	6
102.	Gray and brown conglomerate	14	0
103.	Inferior *coal*, with metallic fracture	9	5
104.	Gray argillaceous shale	3	6
105.	Sandstone, stained red	8	0
106.	Gray and brown conglomerate	23	0
107.	Gray argillaceous shale	11	0
108.	Brown and gray conglomerate	118	0
109.	Bright *coal* found in shaft No. 4, impregnated with iron pyrites	13	0
110.	Gray under-bed	4	0
111.	Black argillaceous shale	4	0
112.	*Coal*	0	8
113.	Black argillaceous shale	4	0
114.	Thin-bedded sandstone	26	0
115.	Gray and brown conglomerate	23	0
116.	Bright *coal*, impregnated with iron pyrites	16	6
117.	Carbonaceous shale	6	0
118.	Sandstone	60	0
119.	Black argillaceous shale	6	0
120.	Gray sandstone, coarse-grained	2	7
121.	Red sandstone	1	0
122.	Gray sandstone	1	8
123.	Black carbonaceous shale	0	4
124.	Dark-gray shale	1	8
125.	Light-gray argillaceous shale	1	8
126.	Black bituminous shale	2	2
127.	Brown sandstone	1	1
128.	Black carbonaceous shale	0	6
129.	Brown sandstone	1	1
130.	Black carbonaceous shale	1	2
131.	Inferior shaley *coal*, found in shaft No. 2	12	0
132.	White sandstone	5	0
133.	Black bituminous shale and coal	5	0
134.	Yellow sandstone, irregular	1	0
	Carried over	...3,271	4

	Brought forward...	3,271	4
135.	Inferior coal and bituminous shale mixed, found in shaft No. 1	20	0
136.	Dark-gray under-bed	6	0
137.	Hard and compact gray sandstone, conglomerate	60	0
138.	Black siliceous rock, with a conchoidal fracture, and containing flakes of vegetable charcoal	21	0
139.	A bed of inferior coal	15	0
140.	Gray argillaceous shale, with thin beds of sandstone	26	0
141.	White and light-gray sandstone, conglomerate, containing boulders of white quartz 12 inch diameter	325	0
142.	Greenish-gray argillaceous shale, alternating with thin beds of sandstone	200	0
143.	Greenish-gray argillaceous shale, containing large concretions of gray limestone	153	0
		4,097	4

The first six beds of the above, embracing a thickness of 993 feet, belong to the ironstone shales; the beds 141, 142, 143, being 678 feet, belong to the Talchirs. Thus the thickness of the Lower Damúda group is, by Mr. Williams's measurements, 2,426 feet. This is probably very nearly correct, but as it may be slightly too high, 2,000 feet may very safely be taken as the minimum thickness.

The above section shows the existence of fourteen beds of coal known to equal or exceed 3 feet in thickness; of these, however, several are of similar quality to those already mentioned as occurring in the neighborhood of Barmúri. It has not always been found possible to recognize the seams mentioned by Mr. Williams, probably in consequence of the out-crops having been covered by changes in the course of the stream, since the time of his visiting the locality.

Dumarkhúnda seam.

No. 10, which is called the Chánch seam, is probably that now worked at Dumarkhúnda, the identification of which with the Chánch seam is doubtful, the latter being probably higher in the series, and nearer the base of the ironstone shales. The Dumarkhúnda seam has hitherto only been worked on

the out-crop, but a deep shaft is now (1860) being sunk. The mine is the property of the Bengal Coal Company, as are also those of Chánch and Núchibád, the former East, the latter West of the Kudiá stream. They lie about a mile South-west of Dumarkhúnda. The coal, which has a thickness of about 10 feet, has hitherto only been worked by quarries, and by workings carried in from the out-crop. It is of fair quality, and, like many other seams in the Lower Damúdas, *e. g.* Barmúri and Lálbazár, has a concretionary structure. However this may have been produced, there can be no doubt that it is due to action subsequent to the consolidation of the coal, and not to the "original form of the vegetation (probably drifted wood"), as suggested by Mr. Williams, page 74, nor to pebbles of coal washed out of another bed previously deposited, as supposed by Mr. Homfray,* and as was at first believed by Mr. Piddington,† who, however, on receiving additional specimens in better condition, immediately saw that the structure was of later date than the formation of the coal.‡ This it evidently is, for the curved surfaces of the nodules are clearly seen to pass across the laminated structure parallel to the planes of stratification, which is so strongly marked in all Damúda coal. The nodules, indeed, have all the appearance of concretionary action, but whether that is due to chemical action alone, or to heat, or to both combined, it is difficult to say.

Chánch and Núchibád.

"Ball coal."

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* Second paper, page 26.

† On the ball coal of the Burdwan mines, *Asiatic Soc. Jour. Beng.*, Vol. XVII., page 60.

‡ *Asiatic Society's Journal*, Vol. XVIII., page 412, and Vol. XIX., page 76.

Mr. Piddington attributed it to heat under pressure, and showed its analogy to columnar structure.

Mr. Williams also, in writing of the Ramghur coal, which possesses the same structure, says —"These concretionary nodules have been erroneously supposed to be drifted boulders of coal of a prior origin, which is manifestly not the case ; it is, in fact, a structure common to the coal itself," &c. &c., page 28.

Seam near Patlabári.

Not far North-west of Chánch, a mine was worked for a short time in 1855 or 1856, by the Bengal Coal Company, in a seam 20 feet thick, near Patlabári. Very little coal was taken out.

Jhelia section.

To return to the seams cut through in the Jhelia stream, and to Mr. Williams's section, Nos. 21, 30, and 43 were only partially explored by Mr. Williams, the pits sunk to prove them being stopped by water. All are thicker than the amount given, but it is not known how much. The ground where their out-crops were discovered is now the bed of a large tank, so that nothing can be seen of them.

No. 53—9 feet thick, is described by Mr. Williams* as a coking coal of excellent quality. A Company was formed to work it, and other beds, and a shaft sunk at Kumardhúbi. But disputes arose between rival Companies, and the land fell into the hands of the Bengal Coal Company, who abandoned the mine; it is said by their agents, on account of the bad quality of the coal.

This bad quality, if the statement be correct, may have been due to either of two causes, both of which have frequently been alluded to as influencing the seams of the Lower Damúdas. It is not probable that Mr. Williams, who, from long experience in coal mines, was peculiarly capable of forming a correct opinion, was deceived in his estimate of the excellence of the coal at the spots where he excavated; but from the great tendency of the seams of the Lower Damúdas to vary in quality, it is quite possible that, at 50 yards distance, the coal may have been poor.† In this case, however, there is little doubt that the coal near

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Nearly all the details concerning these beds are taken from Mr. Williams's Report. He sank small shafts upon the seams, and, consequently, had better means of judging of their quality than the present Survey.

† It is only fair to state that, in the strong opinion I have expressed throughout as to the inferiority of the seams of coal in the Lower Damúdas, I differ from those who have preceded me in the examination of the field. At the same time, I had the advantage of

the shaft was hardened by trap, and the seam mined elsewhere may prove of good quality.

Of the next seams seen, No. 59, 16 inches thick, and No. 65, 8 inches, are stated to be of the best quality of coking coals; their size, however, would prevent their being extracted by the present system: seams also of so small dimensions may very possibly thin out in these beds within a few yards. No. 82, 10 feet thick, is very inferior, but No. 86, seen just South of the bridge on the Grand Trunk Road, and 7 feet 6 inches thick, is apparently of good quality, and is probably that already spoken of as having been cut into in a well at Táldánga dâk bungalow. A thin seam is seen just North of the bridge.

A little further up is seen No. 103, 9½ feet thick, of very inferior shaley coal. The two seams, 109 and 116, which are said to be of fair quality, are seen about a quarter of a mile from the Grand Trunk Road, and may be traced for some distance towards Hejiakhúnd. The seams, however, which cross the road West of Hejiakhúnd are not clearly continuations of those last mentioned; it appears rather as if the more Easterly seams died out, and others came in nearly on the same general level in the series. All seams below these are described by Mr. Williams as worthless, and only two are seen, and those by no means well, in the banks of the stream.

Section in the Kúdia stream.

In the Kúdia only thin strings of coal occur as far as Sángamahal, and South of it, the few beds seen are too much disturbed by the neighborhood of the fault, bounding the field to the South-west, to be of any use. Just South

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being acquainted with the researches of the few previous observers, and I went to the spots fully impressed with their estimate of the richness of the district, and the excellence of the coal. Nor did I change my opinion without ample evidence to the contrary. Nevertheless, I may be mistaken, or it may so happen that only some seams are variable in size and quality. That a very large proportion are greatly injured by trap is unquestionable. As will be seen, the evidence in the Rániganj series is different, and there is far more evidence of seams being continuous over considerable areas.

of the Grand Trunk Road, a little East of Bindrabandpúr, two seams of coal, each about 10 or 12 feet in thickness, crop out separated by 5 or 6 feet of shale. Two other seams occur between this point and the Kúdia: of one of these only traces are seen, the other is 4 feet in thickness.

South of Nirsha.

There can be little doubt that very many seams are concealed by gravel, clay, and other surface accumulations, since throughout the West of the field, almost wherever sections exist, coal seams are numerous. Of all sections, however, none equal those seen South of Nirsha, in the Kúdia stream, in the quantity of coal.

In the Pasai stream.

The Pasai runs into the Kúdia about quarter of a mile South of the bridge on the Grand Trunk Road, over the first-named stream. In the Pasai a seam of coal, 9 feet thick, is seen, the lowest in the following section. Down the Kúdia, from the junction of the two streams, but few seams are met with, and these of inferior quality, and thin. Two, of 2 and 3 feet in thickness respectively, crop out some distance down the stream, and at Sangamahál the seam formerly worked there is seen. It is 5½ feet thick, and the quality was, by Mr. Williams, stated to be inferior and similar to that at Barmúri. About this the beds are turned up by the fault forming the South-west boundary of the field, and dip North.

Proceeding in the other direction, from the Pasai, *i. e.* to the Westward and up the Kúdia, a magnificent section of the Lower Damúda beds is seen dipping at about 15° or 20° to the South-west.

The highest measurable section is seen at the first bend of the stream below Pitakári, thence in descending order the following beds are seen:—

		Ft.	in.
1. Sandstone and shale	... ...	10	0
2. *Coal*	... ...	6	0
	Carried over ...	16	0

		Ft.	in.
	Brought forward ...	16	0
3.	Carbonaceous shale	5	0
4.	Shaley sandstone	5	0
5.	Carbonaceous shale	2	0
6.	*Coal*, shaley in parts	7	0
7.	Shaley sandstone and some carbonaceous shale, with strings of *coal*, about	30	0
8.	*Coal*, good	7	0
9.	Shaley sandstone	4	0
10.	Coarse, brown gritty sandstone	5	0
11.	Shale, sandy	2	0
12.	Sandstone	2	0
13.	Carbonaceous shale and *coal* of variable quality	4	0
14.	Shaley sandstone	6	0
15.	Carbonaceous shale and *coal*	5	0
16.	Shaley sandstone	13	0
17.	*Coal*, variable, about	7	0
	Total ...	120	0

Here the stream turns to the South-west, and continues along the strike of the beds. The coal seam, No. 17, is seen towards the next bend to the North, to have gained in thickness at the base, the sandstone and shale beneath it passing into coal along the strike. From this spot the section is magnificently seen in the bed of the stream.

		Ft.	*in.*
		120	0
	(Repeated) shaley sandstone		
	(Ditto) *coal*, 13 feet, passing at the base, into		
18.	Carbonaceous shale	6	0
19.	Sandy carbonaceous shale and shaley sandstone	9	0
20.	Grit, variable and thinning out, *coal*	0	6
21.	Shale and shaley sandstone	4	0
22.	Quartzo-felspathic grit	18	0
23.	Carbonaceous shale and *coal*	3	0
24.	Grit and shaley sandstone	5	0
25.	Carbonaceous shale	2	0
26.	Quartzo-felspathic grit	16	0
27.	*Coal*	1	0
	Carried over ...	184	6

Brought forward ...	184	6
28. Shaley sandstone	3	6
29. *Coal*	14	0
30. Grit, intercalated and thinning out close by	5	0
31. *Coal*	1	0
32. Shaley sandstone, with strings of *coal*	7	0
33. Shaley sandstone and shale	10	0
34. *Coal*, shaley towards the top	15	0
35. Shaley sandstone	7	0
36. Carbonaceous shale and inferior *coal*	5	0
37. Carbonaceous shale, some sandstone, and some layers of *coal* interstratified	8	0
38. Sandstone and shale of various kinds interstratified	10	0
39. Carbonaceous shale becoming more coal-like towards the base ...	7	0
40. *Coal*, best towards the base	10	0
41. Thin shaley sandstone	7	0
42. Carbonaceous shale	8	0
43. Grayish and brown sandstone, with interstratifications of carbonaceous shale, coarse and fine	34	0
44. Carbonaceous shale, with interstratifications of somewhat ferruginous, calcareous, and carbonaceous sandstone	20	0
45. Hard calcareous sandstone	1	0
46. Carbonaceous shale and shaley sandstone	12	0
47. Hard calcareous sandstone	1	0
48. Shaley sandstone	7	0
49. Hard, gray calcareous sandstone	1	0
50. Dark-gray shaley sandstones, carbonaceous in parts, with thin calcareous bed	23	0
51. Hard, gray calcareous sandstone	1	0
52. Shaley sandstone, ferruginous, thin-bedded and rippled, passing down into sandy carbonaceous shale	44	0
53. Carbonaceous shale and *coal*	10	0
54. Thin ferruginous sandstone and shale	13	0
55. Coarse felspathic sandstone and grit	4	0
56. Shaley sandstone and shale	3	0
57. Carbonaceous shale	3	0
58. Thin brown sandstone, in parts carbonaceous, with some shale interstratified	12	0
59. Carbonaceous shale and some *coal*...	5	0
60. Thin shaley sandstone	3	0
61. Coarse, white quartzo-felspathic grit	4	0
62. Sandstone and carbonaceous shale	2	0
Carried over ...	405	0

	Brought forward ..	405	0
63. *Coal* of good quality		4	6
64. Light-gray shaley sandstone, felspathic		4	0
65. Carbonaceous shale		2	0
66. *Coal*, shaley in parts	27		
67. Ditto, cut up by trap	5		
	—	32	0
68. Coarse felspathic sandstone		9	0
69. Carbonaceous shale		2	0
70. *Coal*, shaley in parts		8	0
71. Interstratifications of blue shale and felspathic sandstone ...		7	0
72. Quartzo-felspathic grit		3	0
73. *Coal* and carbonaceous shale		2	0
74. Fine sandstone, reddish-brown		2	0
75. Bluish-gray shale		3	0
76. *Coal*		2	0
77. Carbonaceous shale and sandstone interstratified		4	6
78. Fine, thin-bedded, white sandstone, with layers of carbonaceous shale		3	0
79. Coarse, white, gritty sandstone		7	0
80. Red sandstone, with specks of mica		0	6
81. Carbonaceous shale and some *coal*		3	0
82. Whitish quartzose grit		6	0
83. Shale and shaley sandstone		2	0
84. Fine gray and brownish-red sandstone		7	0
85. Shale slightly carbonaceous		2	6
86. Quartzose grit		3	0
87. Shaley, thin-bedded variegated sandstone		1	6
88. Coarse, gritty, massive, false-bedded sandstone, brown and dark-gray, felspathic in parts		30	0
89. Carbonaceous shale		11	0
90. Fine gray sandstone, in distinct beds		14	0
91. *Coal*		1	0
92. Coarse grit and sandstone interstratified		10	0
93. *Coal*, thin, thickness not seen			
94. Fine gray sandstone, about		6	0
95. *Coal*, about		3	0
96. Felspathic sandstone		9	0
97. *Coal*		4	0
98. Carbonaceous shale		2	0
99. Sandy shale and some sandstone		4	0
100. Carbonaceous shale		3	0
	Carried over ...	722	6

	Brought forward ...	722	6
101.	Coarse quartzo-felspathic grit, containing fragments of quartz. This bed breaks up sometimes and becomes shaley towards the top*	80	0
102.	Shale alternating with thin sandstone	9	0
103.	Ironstone of poor quality	0	6
104.	Black carbonaceous shale	5	0
105.	Thin shaley sandstone	2	6
106.	*Coal*, shaley in parts, especially towards the top	9	0
107.	Shale	5	0
108.	Grit, thickness not seen.		
		833	6

Seams of coal in this section.

In this grand section there are altogether twenty-seven seams of coal, of the respective thicknesses of 6, 7, 7, 4, 5, 13, (varying to 7,) ½, 3, 1, 14, 1, 15, 5, 10, 10, 5, 4½, 32, 8, 2, 2, 3, 1, 2, 3, 4, and 9, and an aggregate thickness of 175 feet! But a large proportion of this is merely shale, and, if one-half even be tolerable coal, there is still an enormous thickness. Twenty seams are 3 feet and upwards in thickness, the best of these are No. 2, 6 feet; No. 8, 7 feet, both seen near Pitakári; portions of No. 17, 29, and 40, and No. 63, 4½ feet. Perhaps part of the thick seam, No. 66, might also be workable, but the presence of trap is a great disadvantage. All other seams appear to be more or less shaley.

Further up the Kúdia, beyond Pitakári, and approaching the boundary of the Damúdas near Khúka, many partial out-crops are seen, but no continuous section, and nothing can be determined as to the quality or thickness of the coal seams; the majority of which must be continuations of those in the preceding section. All these seams, if they continue a few hundred yards to the West, must be cut off by the fault between Tilturia and Belkúpa.

* This thick bed of grit occurs at the junction of the Pasai and Kúdia. The remainder of the section is seen in the Pasai.

A seam of very carbonaceous shale is seen in the Pasai, a little North of the Grand Trunk Road. Beyond this, the stream, for a long distance, exposes no section, and the next coal seen occurs a little South of Pathápidhi. This is about 10 feet thick. On the same horizon, and possibly in continuation of this seam, an out-crop of a bed, about 8 feet thick, occurs North of Patlakúri, and extends to the boundary near Bareghar. At no great distance beneath this, one or two other seams of unknown thickness are seen, and just above the top of the Talchir beds, a very thick seam, 30 feet altogether, but very shaley in parts, crops out along the stream for nearly half a mile, presenting a very peculiar appearance. This seam is again intersected by the Pasai, at the extreme point to the West, to which Lower Damúda rocks reach. The base of the Lower Damúdas is not more than 30 or 40 feet below the last-mentioned seam of coal, and the lowest rocks of that series consist, in this locality, of hard, grey sandstones and shales, the white sandstones and conglomerates, which formed the base from near Etiapura, Samdi, and the Barákar, having disappeared. Near the Pasai there is unconformity between the Damúdas and Talchirs.

Many of the seams along the Pasai and Kúdia streams are occasionally worked by the inhabitants of the villages around, and small quantities of coal obtained. But such desultory workings never result in more than the digging out of a few hundred maunds from the banks of the streams.

CHAPTER IV., SECTION 3.—*Ironstone Shales.*

Bad sections.

So few sections of these rocks are seen, that any detailed description of them is impossible. They are, throughout, almost of the same mineral character, consisting of a very fine black carbonaceous shale, which breaks up into small

angular fragments, and in which seams of argillaceous iron ore, varying in thickness from 2 inches to a foot, occur at irregular intervals.

Uniform mineral character.

Throughout the area represented upon the map, as occupied by these beds, the argillaceous carbonate of iron is common, but it appears to be both more abundant and of better quality towards the top than near the base of the series.

Though sections, even the smallest, are rare, fragments of the ironstones generally occur upon the surface so abundantly as to mark well the area covered by the out-crop of these beds. They appear, despite their softness, to resist atmospheric denudation better than the harder grits or sandstones which rest upon or underlie them, for the ironstone shales form a high ridge, stretching across the country. This is probably due to their resisting the corroding action of water containing carbonic acid better than the felspathic ingredients of the sandstones.

Section near Bagonia.

Sandstones occasionally occur, especially towards the base of these beds. On the banks of the Barákar, at Bagonia, the following section is seen :—

(Descending.)

	Ft.	*in.*
1. Ordinary ironstones and shales, containing a few thin bands of micaceous sandstone.		
2. Rather coarse felspathic and micaceous sandstone, thickness not quite certain, as a slight throw occurs, but probably within a foot or two	12	0
3. Hardened carbonaceous shale	6	0
4. Trap, intrusive	1	3
5. Hardened carbonaceous shale	0	6
6. Blue micaceous sandy shale	7	6
7. Blueish thin-bedded micaceous sandstone	25	0
8. Hard massive felspathic sandstone	1	0
9. Coarse felspathic sandstone, micaceous and false-bedded ...	4	0
10. Shaley micaceous sandstone, passing down into	12	0
11. Black carbonaceous shales and ironstones, Lower Damúdas ...	20	0
Total	89	3

Quantity of ironstone.

It is difficult to form an accurate estimate of the quantity of ironstone contained in these beds; it varies throughout. In one place, near Jámsul, in 150 feet of beds, 26 runs were met with, varying in thickness from 2 inches to about a foot, and occurring at intervals of from 6 inches to 10 feet from each other. The whole thickness, taking the average of each seam at 4 inches, was 8 feet 8 inches or about $\frac{1}{17}$ of the whole. This is probably about the average of the upper part of the beds. It is exclusive of many nodules from 6 inches to 3 feet in thickness, which are not regularly interstratified, although, like similar nodules in the English ironstone formations, they may be found to recur on about the same horizon for considerable distances. None of the seams appear to be continuous over large spaces, all thin out. There is, therefore, a probability that an attempt to follow up any particular seam or seams by mining would not be successful. But where some seams thinned out, others would come in, and therefore, in quarrying, or in mining by large excavations, a tolerably uniform produce might, on the whole, be expected.

Mr. D. Smith's examination.

Mr. David Smith,* when examining the iron districts of Bengal, on account of Government, endeavored to test the richness of the ironstone shales by sinking a pit † in the neighborhood of Bádúl (Barrool), to a depth of 52 feet, and in that

* Mr. David Smith's *Report to the Government of India on the Coal and Iron Districts of Bengal.* 1856. Mr. Smith does not appear to have been well acquainted with Mr. Williams's previous work in the Ráníganj district, nor to have understood (if he saw) the map, in which the boundaries of the ironstone shales are laid down. Unfortunately these boundaries have been marked in the map by white lines, indicating "dykes or faults," and Mr. Williams's Report is difficult to understand without a very accurate knowledge of the district. Mr. Smith's remarks on the area of the iron-producing strata show that he was not aware of its extent, nor of the circumstance of the beds between Niamatpúr and Táldánga, being merely a continuation of those in the neighborhood of "Barrool" (Bádúl). He is also, I think, in error in considering seams of ironstone as necessarily continuous throughout the whole of the iron-shale area. These objections in no way detract from the value of Mr. Smith's Report, which relates essentially to metallurgical and mineralogical, and not to geological questions.

† Marked in the Revenue Survey Map as a *copper mine!*

depth passed through four seams, amounting in the aggregate to a thickness of 18 inches of clay ironstone, and 52 inches, in two seams, of black band, all of good quality, besides 18* inches of inferior black band. This gives $\frac{1}{12}$ of black band, and $\frac{1}{34}$ of clay iron ore, altogether about $\frac{1}{9}$; but the inferior richness of the black band would render the quantity of iron extracted from the ore obtainable from a given area very little larger than in the case of the other section above quoted.

One note-worthy circumstance, which would be of great advantage in mining these beds, is their impermeability to water. Mr. Smith's shaft, after standing open for three years, had only a few feet of water at the bottom: almost every where else throughout the field, shafts, after being left for a season, fill with water.

"Black band" ore.

Black band or carbonaceous clay iron ore is by no means rare throughout the ironstone shales, though the shaft at Bádúl probably supplied an exceptional case of its abundance, as in general there is less of it than of the ordinary clay iron ore. Considerable quantities occur around Birkúnti, North of Bádúl.

CHAPTER IV., SECTION 4.—*Ránigani Series.*

Sub-division into districts.

THE large area upon the map occupied by the rocks of this group, and the number of coal seams worked within its area, render it necessary to sub-divide it somewhat before proceeding to describe its local peculiarities in detail. In the same manner as with the Lower Damúda, the most convenient plan appears to be to commence the description on the East. The tract lying North of the River Damúda will be treated of before the area to

* Mr. D. Smith says 38 inches, but this comprises three seams of 8, 9, and 3 inches respectively, which were not intersected in the pit.

the South. The area may, consequently, be thus subdivided, and the sub-divisions described in the succession in which they are placed below.

1. The country East of the Singáran.
2. Valley of the Singáran.
3. Ràniganj and its neighborhood.
4. Valley of the main stream of the Núnia, and of the Eastern and central branches North of the Grand Trunk Road, in short, East Division of the Núnia.
5. West division of ditto, *i. e.* the valley of the West branch of the Núnia.
6. Chinakúri and its neighborhood, with the country to the West, as far as the Barákar.
7. The country South of the Damúda, commencing from the West.

I. *Country East of the Singáran.*

1. Of the district East of the Singáran, but little need be said.

Rocks not well seen.

The rocks forming a high ridge West of Khyrasol, and which are well seen in the railway cutting near Kalipúr, form no part of the Damúda Series. The whole tract to the West of them, for 8 or 10 miles, is concealed by laterite on the higher ground, and alluvium in the lower. In stream sections through the laterite, sandstone is occasionally seen, which probably belongs to the Damúda formation, this is certainly the case near Barpahári, in the neighborhood of the Adjai. South of Andál, on the Grand Trunk Road, a small patch of sandstone, apparently belonging to the Damúda beds, is seen to rise through the alluvium.

Probable extension of coal.

It is a most interesting question whether the coal-bearing deposits extend beneath this tract of country, and further to the Eastward, beneath the alluvium and laterite of the Burdwan District. Every possible attention

has been paid to the elucidation of this point during the progress of the Survey, but the conclusions arrived at are purely of a negative character. There is no direct evidence to the effect that the Damúdas extend further East than the neighborhood of Andál and Ukra. But neither is there any evidence, direct or indirect, to show that they are here cut off; indeed, if they were so, and the hard metamorphic rocks succeeded them, it is probable that hills of the latter would jut up somewhere within the extensive laterite area, which stretches from Rániganj to the neighborhood of Burdwan. The field is at its widest where it disappears beneath the alluvial deposits, and, although there is nothing in the least improbable in the occurrence of a fault a short distance to the East, which may cut out all the Damúda rocks, not the slightest indication of such a phenomenon exists. Nor is it probable that the sandstones of Khyrasol and Kalipúr are in that place of any great thickness, and a boring, to the depth of 200 or 300 feet, would probably suffice to ascertain the presence or absence of the Damúda rocks beneath them. At the extreme East of the field, the coal at Harispúr colliery is of excellent quality, and lying nearly horizontal, so as to be easy to work, and there can be little doubt that coal seams equally valuable will be found further East, if the ground be properly and systematically explored by sinkings or borings. How far East they may be found, is impossible to say.

It is stated by Mr. Williams* that coal was found at Jánjura, about 2 miles East of Ukra, at a depth of only 20 feet from the surface. No details are given, and enquiries upon the spot have failed in ascertaining any facts, either in confirmation or contradiction of the statement. There is nothing improbable in the circumstance, but Mr. Williams does not state whence he derived his information.

* Report, page 20.

II. *Singáran Valley.*

The Singáran rises in the extreme North of the area occupied by the beds of the Rániganj series. Just beyond its valley, near Bádúl, the lowest beds are seen resting on the ironstone shales. They consist of thin-bedded micaceous sandstones, and the same appear frequently at the base of the series throughout, resting on the somewhat sandy black shales, which form the top of the rocks containing ironstone.

Lowest beds.

For some miles South of this very little rock is seen. About $1\frac{1}{2}$ miles West of the Singáran, a seam of coal crops out in a tank just East of the village of Damúdapúr. Upon this two pits were sunk by a zemindar, and it is stated that 4 or 5 feet of coal had been cut through, when the quantity of water met with stopped the workings. Near this the country is, for the most part, covered with laterite. Coal is marked in Mr. Williams's map upon the small stream flowing from Núndi, about half a mile from the spot where it joins the Singáran. Nothing but carbonaceous shale is seen.

Coal at Damúdapúr.

Reports of the occurrence of coal, and of its discovery by boring, or in tanks and wells, are current throughout the district. To these reports, as well as to statements of its non-discovery, very little credit can be attached.* Nothing is seen in the Singáran itself, except beds of coarse massive sandstones, and these are only at wide intervals, there being much alluvium.

Near Chokidánga a better section is seen, some coarse micaceous sandstones, brownish-yellow in color, and containing a small seam of

* In one instance several wells had been sunk to a considerable depth to try for coal, and on my enquiring from the Gomashta of the Zemindar of the village, who was the ostensible agent, I was assured that none whatever had been found. I made particular inquiries, not only in the village itself, but in others around, for I had previously learned that coal had been found. All my enquiries were fruitless. I was shown the pits, and assured that nothing had been cut. A few months afterwards a colliery was at work upon the spot. I quote this case merely to show the difficulty of obtaining reliable information.

coal, 2 or 3 feet thick, are overlaid by thin sandy shales, containing *Glossopteris*. Upon these rests the coal seam worked at Chokidanga and Mámudpúr, the former colliery belonging to Messrs. Nicol and Sage, the latter to the Bengal Coal Company.* Mámudpúr has hitherto only been worked as an open quarry.

The section of the seam at Chokidánga is

	Ft.	in.
Sandstone and shale.		
1. *Coal*	3	0
2. Shale	0	6
3. *Coal*	6	6
4. Shale	0	3
5. *Coal*	5	0
Shale, 6 inches.		
White sandstone.		
Total thickness of seam ...	15	3
Coal in ditto ...	14	0

At Mámudpúr:—

	Ft.	in.
Sandstone and shale.		
Blue shale	6	0
Coal	1	0
Blue shale	0	4
Coal	3	6
Blue shale, with strings of coal variable, average about	2	3
Coal not seen, said to be	7	6
"Hard rock"	0	0
Total thickness of seam ...	14	7
Coal in ditto ...	12	0

showing a wide difference from the other section, which is at a distance of not more than half a mile.

The whole of this seam near the out-crop, for some distance, on both sides of the Singáran, but especially to the East of the stream, has been worked out. The colliery extends on the East as far as a fault, which

* Mámudpúr was till lately worked by a native.

throws down the coal on its Eastern side about 150 feet, and throws the out-crop to the South about a quarter of a mile. The direction of this fault is North 33° West. The "backs" or jointing in the coal vary greatly: near the fault they are* North 35° West and North-east; in another place West 5° North and North 25° East; in another again, North 5° West and East 20° North. At Mámudpúr they are East and West and North 10° East in the coal, but there is jointing in the shale above, North 25° East, which is not seen in the coal seam.

This seam appears to be cut off on the West side also by a fault, for two shafts were sunk at Sathakpúr, about a quarter of a mile South-west of Mámudpúr, to a depth of nearly 200 feet, without any coal being cut; it must necessarily have been found had the seam continued steadily and without interruption.

Dhosul.

Passing down the Singáran, about half a mile below Chokidánga, there is an old quarry filled with water. No rocks are seen in its neighborhood. The seam is variously stated by natives about the place to have been 7 feet or 3 feet in thickness. Mr. Williams says it was reported to be 12 feet in thickness.† Its quality was probably inferior. The mine was opened by Mr. McSorly, about the year 1843 or 1844, and the site is within the boundary of the village of Dhosul.

Tapassi.

The next seam of coal met with is one, which, from its size, and also from the very variable quality of the fuel it affords, recalls the great beds of the Lower Damúda. It is 22 feet in thickness, without partings of shale, and is overlaid by 3 feet of blue shale, upon which rests sandstone. The high dips of 10° and 15° prevailing about Chokidánga are here succeeded by nearly

* That is, there are two backs, one striking North 35° West and South 35° East. The other North-east to South-west.

† Report, page 28.

horizontal stratification, the beds not being inclined more than from 3° to 7°. The direction continues to the South-east.

In this huge seam there are two sets of workings, both belonging to the East India Coal Company. One a quarry, situated at Dhosul, East of the Singáran, the other a mine at Tapassi, West of the stream. The former has long been worked upon the extreme out-crop of the coal; the latter, after being abandoned for many years, was recommenced in 1857: in the mine, 11 feet, in the middle of the seam, is extracted, leaving 5 or 6 feet above and below. Just West of the colliery, at Tapassi, is a fault with a down-throw to the West, probably the same as that which throws the coal seam East of Chokidánga. The quarry of Dhosul lies West of this fault, which is of small extent here.

Jorjánki.

The out-crop of the Tapassi seam can be traced for more than half a mile to the East of the Singáran, towards the village of Jorjánki. It is marked throughout by pieces of burnt cinder, showing that like many other seams in the district, it has been on fire at the surface. The out-crop lies some distance within the boundary of Dhosul village, but as the dip is small, there can be no doubt that this fine seam underlies the whole of the Western part of the land belonging to the village of Jorjánki, at a depth of not more than 150 or 200 feet at the outside. The extent is probably greater than merely a portion of the village lands, but there are so many faults in this part of the country, that nothing is certain, the evidence of which is not seen, and all the country around Jorjánki is covered by laterite.

The Tapassi seam is probably about 400 or 500 feet above that at Chokidánga The exact depth of the latter below the former cannot be measured, as no continuous section exists between them.

Out-crop seen in Singáran stream.

About a quarter of a mile South of the Tapassi seam, the intervening rocks being coarse sandstones, about 150 feet thick, a small seam of inferior coal is seen, which is largely worked near Jorjánki, although, from its quality, it can be only used

for brick burning. Three or four quarries belonging to various proprietors are at work. The dip is 5° to 10° South 30° East, and the section in Messrs. Acland and Co.'s quarry is:—

		Ft. in.
Shale and sandstone about		10 0
Hard gray sandstones		1 0
Shale and sandstone interstratified		6 6
Dark shale		0 6
Gray sandstone		1 10
Coal	3 10	
Shale	0 2	
Coal	0 10	
Shale	0 2	
Coal	1 0	
Total of seam		6 0
Coal in ditto		5 8

The section, as usual, however, shows some variation, and in the next quarry becomes

Coal	4 6	
Shale	0 4	
Coal	0 9	
Total of seam		5 7
Ditto Coal		5 3

No deep workings whatever have been made upon this seam, but the whole out-crop, or nearly the whole, appears to have been extracted.

Between Jorjánki and Parasia, the section in the Singáran is fragmentary, no regular succession of rocks being seen, and the valley being filled in most parts with alluvium. So far as can be made out, the beds appear to dip regularly, but there is no doubt that the whole district is much disturbed by faults, some of them probably of considerable size. Two small seams of coal, the largest only 3 feet thick, occur within 80 or 100 feet above that worked at Jorjánki. The dip becomes more Eastwardly, and the burnt out-crop of a large seam is seen about 1 mile East of the village of Kolasturi. It is possible

that this seam, which dips about East 5° South, may be identical with that now worked at Parasia mine. The dip at the mine is East by North, but less than a quarter of a mile to the Eastward two small seams of coal are seen in the Taladári Khál, dipping to the South-east. The thickness is about 3 feet and 1 foot respectively, but they are ill seen. In the stream which runs between Kamda and Parasia, the out-crop of another seam is seen, about a mile above the junction with the Singáran. Its thickness cannot be made out.

Few tracts about Rániganj are more promising than that lying immediately East of the Singáran. There is no doubt but that coal exists, the dips are in general low and favorable, and the distance from the railway will be small, when the new line along the Singáran valley is completed.

Parasia mine.

Parasia colliery, now the property of the East India Coal Company, lies close to the left (East) bank of the Singáran. The mine is 110 feet deep, and the seam has been dug into a depth of 13 feet, but it is not known whether more coal underlies it or not. It is consequently difficult to judge what bed is being worked, as the whole section is not exposed: 7 feet in the centre of the seam is mined, and is of better quality than the remainder. About a quarter mile to the South-west, on the opposite bank of the Singáran, and in Bánsra village, a shaft was sunk some years ago, and coal was found, in all probability the same as that now worked at Parasia, for the draining of the mine at the latter place has sensibly diminished the water in the Bánsra pit.

Kúlastori.

About half a mile West of this pit, at Kúlastori, a shaft was sunk by the East India Coal Company, but although some very carbonaceous shale was cut through, no workable coal was found.

Mangalpúr.

The next mine to the South, Mangalpúr, is one of the most important in the district. It lies about a mile due South of Parasia, and is the property of Messrs. Erskine and Co. It is worked by means of both shafts and quarries upon a seam of coal, of which the following is the section:—

		Ft.	in.
	White sandstone, felspathic, over 100 feet.		
a.	Inferior *coal* and shale	9	0
b.	Good *coal*	8	0
c.	Shale	0	0
d.	*Coal*	0	6½
e.	Shale	0	0½
f.	*Coal*, good	3	6
g.	Shale	0	3
h.	Coal	0	6
i.	Shale	0	1
j.	Coal	2	6
	Shale.		
	Total thickness of seam	24	5
	Coal in ditto	15	0
	Or in places 24 feet.		

The dip is North-east, about 7°. Just East of the Singáran, and South of the village of Sonachora, the coal is cut off by a fault, the direction of the throw of which has not been ascertained. A large trap dyke, about 6 feet in breadth, runs through the colliery from W. N. W. to E. S. E., and to the South of this the coal is nearly exhausted on the West side of the Singáran. Pits have now been sunk, and the mine is being worked North of the dyke.

The backs at Mangalpúr strike East 40° North and West 30° North. The out-crop of the coal is marked by a series of quarries, many of them abandoned, which run for some distance up the little valley between the rise on which the colliery is situated, and that upon which, about half a mile South, is the village of Mangalpúr. After running North-west for some distance, the line of out-crop turns North over the ridge; and, if continuous, might be expected precisely where coal is found in

the Bánsra and Parasia shafts. But until the coal in these shafts is cut through, and the section fairly exposed, it is impossible to ascertain, in the presence of the numerous faults which unquestionably exist in the neighborhood, whether the seams are identical or not. If they are, and, as is in that case probable, the burnt out-crop already referred to as occurring in the Singáran, North-west of Parasia, belong to the same seam, the coal must underlie a basin of considerable size. The dips alone would favor this view.

Harispúr mine.

Whether the Mangalpúr seam be identical with that worked at Parasia or not, there can be little doubt about its being the same as that worked at Harispúr and Babúsol, both mines belonging to the Bengal Coal Company. The first-named lies about 2 miles South-east of Mangalpúr mine, the latter rather more than a mile South of the former. At Harispúr the section is :—

				Ft.	*in.*
	Sandstone, white and felspathic.				
a.	Black shale			2	0
a.	Bituminous shale, with strings of *coal*			8	0
b.	Good *coal*			8	0
c.	Shale			0	1
d.	*Coal*			0	6½
e.	Shale			0	1
f.	*Coal*	4	2		
g.	Hard bluish-gray sandstone	0	8½		
h.	*Coal*	0	4		
i.	Blue shale	0	2		
j.	*Coal*	3	0		
	Bluish-gray sandstone.				
	Total thickness of seam			25	0
	Coal in ditto			16	0

The main "backs" are North 10° East, secondary ones about East and West.

The dip is doubtful, the workings not having extended far, and the bed being nearly horizontal, or slightly undulating. Coal has been

found North-east of Harispúr, near Kájra, at a depth of only 40 feet, and if, as is probable, the seam is the same, the dip is probably Southerly or South-west.

Babúsol mine.

At Babúsol the dip is about 5° to the East, the shaft 145 feet deep, and the section

	Ft.	in.
Hard white sandstone	124	0
Blue sandy shale, with impressions of plants	2	0
a. Bituminous shale, with some coal irregularly interstratified ...	8	0
b. *Coal*, good	8	0
c. Shale	0	4
d. *Coal*, about	0	8
e. Shale, thickness not seen	0	0

Beneath this coal again occurs, as has been proved by borings. The mine is a new one. There can be but little question of the identity of the seam with that found at Mangalpúr and Harispúr, and there appears every probability that, beneath the wide space between Harispúr and Babúsol, there is one continuous bed of coal. It is one of the best seams in the district, the quality of the fuel being excellent. The principal backs at Babúsol are North 40° East and North 30° East, cutting each other at a very acute angle, and another secondary series heading North-west.

Surface covered and rocks concealed.

All this country is completely covered with laterite on the higher ground, and alluvium on the lower. How the Mangalpúr seam is brought in at Harispúr and Babúsol can therefore only be matter of conjecture. The coal may lie in a basin, the out-crop extending through Babúsol, to East of Mangalpúr village, crossing the Singáran above Parasia, and thence running South-east to a little North-east of Harispúr; or it may be thrown by a fault between Mangalpúr and Babusol. This would account for no coal having been found in the shafts sunk South-west of the village.

It is probable that the Harispúr and Babúsol seam extends further to the East than is at present known. Its value will, doubtless, induce

the proprietors of Kájra, Diguala, Dakhinkhand, &c., to explore their lands by borings.

III. *Rániganj and its neighborhood.*

Richness in coal.

The small area embraced in this title, and comprising the mines of Gopinathpúr, Bhángaband, Sirsol, Ránigànj, Rogonáthchuk, Damulia, Harabhánga, Nímcha, Jemeri, and Banáli, although not covering a larger area than 20 square miles, produces half of the whole amount of fuel mined in the Ránigànj field.

Obscurity of relations of seams.

But, despite the lights thrown upon its geology by these numerous mines, it is so much cut up by faults, and so little is seen of the surface, that the relations of some of the most important coal seams to each other, and their position in the general section, are, in the last degree, obscure.

Quarry near Mangalpúr.

About half a mile West of Mangalpúr colliery, and close to the Grand Trunk Road, the out-crop of a seam, apparently 4 or 5 feet thick, is seen, in which a quarry was once worked by the Bengal Coal Company. The spot is an excellent one for fossils, and very beautiful impressions of leaves abound in some soft shales beneath the coal.

Gopináthpúr or Bánsra.

About 1 mile West of Mangalpúr, in the village of Gopináthpúr or Bánsra, is the mine known by the first name, the property of the East India Coal Company. It has been worked for a few years. The seam dips to the South, so some peculiar faulting must intervene between this mine and that at Mangalpúr. The seam is 7 feet thick, and is of unequal, and in parts, of inferior quality; its out-crop can be traced for more than a mile to the

Bhángaband.

Bengal Coal Company's quarry at Bhángaband, (formerly worked by a native, and then known as Kántagaria,) which is upon the same seam. The quality of the coal

here is also very variable, and the section is very similar to that at Gopináthpúr. It is

	Ft.	in.
Shale and sandstone.		
Coal	3	6
Shale	0	6
Coal	1	0
Shale	0	2
Coal	3	6
Total thickness of seam ...	8	8
Coal in ditto ...	8	0

This bed probably underlies those at Rániganj. A little West of Bhángaband it appears to be cut off by a fault.

Pits near Khatsuli.

On the opposite side of the Grand Trunk Road, and about half a mile South of Gopináthpúr, are two pits sunk by Mr. Watkins, and in which coal is said to have been found. It was probably the Gopináthpúr seam. At Khatsuli, just East of the bazaar, in the town of Rániganj, two other pits were sunk, and there also coal was found. It is difficult to say what seam can have been cut: possibly that worked at Rániganj.

Sirsol colliery.

Sirsol mine is about 2 miles West of Gopináthpúr, and 1½ S. S. W. of Bhángaband. The coal seam crops out along the East face of a valley to the West of the village, and lies very nearly flat, there being a slight dip of not more than 2° towards the East. The quality of the coal is excellent, perhaps, on the whole, the best yet worked to any extent in the field. The section is not well exposed towards the bottom, even in the quarries, but it appears to be

	Ft.	in.
Sandy shale and sandstone.		
Carbonaceous shale	20	0
Coal	11	6
Shale, sandy	0	4
Coal, said to be	6	0
Total thickness of seam ...	17	10
Coal in ditto	17	6

In the mine no complete section is seen, there is, however, said to be :—

	Ft.	*in.*
Carbonaceous shale...	12	0
Coal, good	12	0
Shale	0	1
Coal, inferior	8	0
Total thickness of seam	20	1
Coal in ditto	20	0

The lower portion of the seam, though inferior to the upper, is still very fair coal. The backs in the quarries strike North 20° West, underlaying to the West, and East 30° North, vertical. In the mine they are slightly different, being North 20° to 30° West, and about East 15° North. The mine is ill worked, the galleries irregular and unevenly cut. A large area of the coal has been extracted from beneath the ground between Sirsol village and the out-crop, but the workings do not extend far either to the East or to the North.

Ránigan colliery.

Ránigan mine, the most extensive in the district, lies rather more than a mile South of Sirsol. The seam dips to the North, or North by East, about 3° in the mine, and at 5° near the out-crop, which runs from West to East, along a little hollow between the villages of Ránigan and Narrainkúri, and has been on fire. The following is the section of the beds above and below the coal, taken from borings made by the Bengal Coal Company :—

RÁNIGANJ NEW MINE.

		Ft.	*in.*
1.	Coarse, white sandstone, soft	14	0
2.	Ditto ditto, hard	6	0
3.	Sandstone yielding water	16	0
4.	Ditto, very compact, with thin wavy seams of coal interspersed	4	0
5.	Blue shale	6	0
6.	Ditto, with numerous fossil plants...	18	0
7.	Clay (indurated) sometimes wanting	0	3
8.	*a.* Carbonaceous black shale	7	10
	Carried over	72	1

		Brought forward ...		72	1
9.	Blue shale, with fossil plants			2	10
10.	*b.* *Coal*	9	0		
	c. Shale	0	3		
	d. *Coal*	0	9		
	e. Shale	0	2		
	f. *Coal*	4	0		
	Total thickness of seam	14	2	14	2
	Coal in ditto ...	13	9		
11.	*g. h. i. j.* Carbonaceous shale			3	10
12.	Blue shale			6	0
13.	White felspathic sandstone			20	0
14.	Very compact sandstone			5	6
15.	Loose, gritty sandstone			12	9
16.	Hard ditto ditto			8	0
17.	Shale, blue and carbonaceous			19	0
18.	*Coal*, Narrainkúri seam...			8	9
19.	Shale, blue and carbonaceous			10	0
20.	Sandstone			26	0
21.	Ditto, very hard			26	0
22.	Blue shale			3	0
23.	Sandstone			3	0
24.	Carbonaceous shale			21	0
	Total ...			260	11

The depth of the last shaft sunk was 162 feet to the top of the coal, the section being

	White felspathic sandstone			130	0
	Blue shale, with fossil plants			21	0
a.	Bituminous black shale			11	0
b.	*Coal*	9	0		
c.	Shale	0	3		
d.	*Coal*	0	9		
e.	Shale	0	2		
f.	*Coal*	3	0		
	Total thickness of seam	13	2		
	Ditto coal	12	9		

While in a pit sunk at the ghât on the Damúda, and just outside the out-crop of the Narrainkúri coal seam, the following section was passed

through, the numbers referring to their equivalents in the preceding sections.

		Ft.	in.
	Surface soil and clay	8	8
19.	Black carbonaceous shale	0	6
	Blue shale	4	3
	Carbonaceous shale, with *coal*	1	6
20 & 21.	Sandstone	4	9
	Ditto micaceous, with thin wavy seams of *coal*	5	0
	Gritty sandstone	6	0
	Carbonaceous shale	1	0
	Sandstone, with scales of mica	2	0
	Blue shale	3	0
	Sandstone	33	0
22.	Blue shale	3	0
23.	Coarse sandstone	3	0
24.	Carbonaceous shale	22	0
	Sandstone.		

The above will also serve to give some idea of the rocks met with in this portion of the series, amongst the highest of the Damúda beds.

Narrainkúri colliery.

No. 18 is a seam formerly worked by Messrs. Jessop and Co., and subsequently by Messrs. Gilmore, Homfray and Co., at Narrainkúri, a village about half a mile South of Ránigan. Its quality was inferior, and when, in 1844, the two Companies, which worked respectively the mines of Narrainkúri and Rániganj, were amalgamated, the former mine was abandoned, and all the available labor transferred to the higher and better seam. A large area near the out-crop has been worked out, the extent being marked upon the ground by the numerous pits. The section of the Narrainkúri coal seam given by Mr. Williams* is :—

				Ft.	in.
13. 14. 15. and 16.	Gray and brown sandstone			40	0
17.	Gray arenaceous shale			10	0
	Coal and carbonaceous shale ...	1	$3\frac{1}{2}$		
	Gray shale	0	6		
	Coal	0	5		
	Carbonaceous shale	0	1		
	Coal, inferior	2	$5\frac{1}{2}$		

* Report, page 48.

			Ft.	in.		
18.	Carbonaceous shale		0	5		
	Coal, inferior		4	1		
	Carbonaceous shale		0	2		
	Coal, inferior		1	10		
	Carbonaceous shale		0	2		
	Coal		2	2		
	Total thickness of seam				13	7
19.	Gray arenaceous shale, with fibre-like impressions of plants				9	2½
	Coal, sulphurous				1	10½
	Gray arenaceous shale				1	2

While Mr. Homfray's section* is

		Ft.	in.
15.	Sandstone	28	0
16.	Ditto, very hard	4	0
17.	Clunch and clay slate (blue shale)	21	5
	Coal	0	3
	Shale and Blackbats (carbonaceous shale)	7	2
18.	Main *Coal*	8	10
19.	Fire clay	4	8
	Black shale	0	4
	Clunch and slate clay	4	0
	Coal	1	6
20.	Sandstone	0	0

There is either error in these various sections, or else they show the Narrainkúri seam and its accompanying shales to be extremely variable, the greatest variation being in the shale overlying the coal. The whole of the Narrainkúri seam is said to be of inferior quality.

Across the Rániganj colliery, from East and West, extend two small trap dykes, which are a few feet apart, each being about 3 feet in breadth, and the mine, before 1843, was wrought mainly on the South side of these, between them and the out-crop. From the practice, which then prevailed, of leaving all small coal which it did not pay to raise, in the mine, and in consequence of the tendency to spontaneous combustion of the

Rániganj old mine on fire.

* *As. Soc. Jour.*, Vol. XI, page 738.

Ránigánj coal, the mine took fire, and was necessarily abandoned; a general sinking of the surface subsequently took place,* so that it is probable the coal remaining as pillars and that unworked, beneath the area occupied by the old mine, was consumed. The extent, however, was small, probably not exceeding 200 yards square. The new colliery North of the dykes is far more extensive, stretching for nearly half a mile from South to North, and but little less at its widest part from East to West. The 9 feet of coal forming the upper portion of the seam are first extracted; the coal is excellent, though scarcely so light as that of Sirsol; that from the two lower seams is even a better fuel for most purposes, but it contains iron pyrites largely, and, consequently, is liable to decompose. Formerly, when all coal was sent to Calcutta by river, and was liable to one, or, in some cases, to two years' exposure to the weather upon the bank, and in the boats, this lower portion of the seam could not be worked, but the facilities afforded by the railway for rapid conveyance have enabled it to be sent to market in good condition, and it is now largely extracted.

Faults near Ránigánj.

The mine at Ránigánj is bounded on the North-west by a large fault,† bearing N. N. E. to S. S. W., having a down-throw to the East. It is probable that the fault increases in amount towards the North, as the beds which, on its Eastern side, dip West, on the West, or up-throw side, dip to the South. Its amount at Ránigánj is probably not much more than 150 feet; what it may be further North it is difficult to say, and it is impossible to ascertain, until the workings are far more extensive, how far it may be complicated by being split or by cross faults. If continuous, it would pass between the Ránigánj and Sirsol collieries,

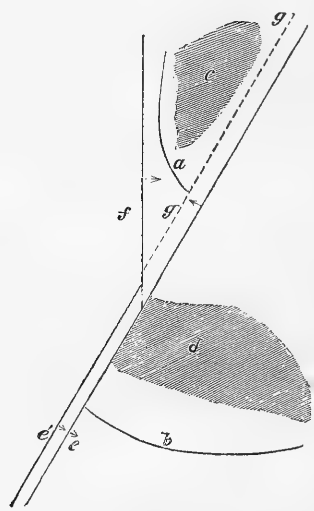
* Mr. Williams's Report, page 40; and his statement is borne out by the appearance of the surface.

† More correctly by two, or, in one place, three parallel faults very near each other. They are, however, in all essentials, equivalent to one large fault, and may be considered as such.

isolating them from each other, and complicating the relations of the coal seams.

From this fault there branches due North, along the line of a small dyke, which runs up the valley towards Sirsol, another fault having the same down-throw to the East. Between these two faults the Rániganj seam exists, at a depth of 30 feet greater than to the East of the N. N. E. fault, so that the continuation of that fault here, or a fault apparently in continuation, and with the same strike, has a down-throw to the West, instead of the East.

FIG. 6. SKETCH SHOWING THE SUPPOSED RELATIONS OF THE RANIGANJ AND SIRSOL COLLIERIES.



a. Outcrop of Sirsol seam; *b.* Outcrop of Raniganj seam; *c.* Sirsol Mine; *d.* Raniganj Mine; *ee.* N. N. E. faults; *f.* N. and S. fault; *g.* Possible fault. The arrows show the direction of the down-throw.

But we have no certainty that there may not be another fault between this area and Sirsol. It is very possible that there is, otherwise the Sirsol coal is probably 200 or 300 feet higher in the series than the Rániganj seam; and, in this case, sinkings through the Sirsol coal will reach the Rániganj seam. But if, on the other hand, the North and

South fault is of small extent, and a large fault separates the two collieries, the Sirsol coal would be lower in the section than that of Rániganj. It is improbable that they should be identical, there is so great a difference in their sections, and the partings of the Rániganj coal are quite distinct from those seen in the mine of Sirsol.

Relations of Rániganj and Sirsol seams.

At the same time that there is so much difference between the Ráni-ganj and Sirsol seams, there are remarkable points of resemblance between the former and that of Mangalpúr, but before entering upon these, it will be well to specify what other seams are known to exist around Rániganj.

Rogonáthchuk mine.

In the first place, to the South-east, at a distance of about $1\frac{1}{2}$ miles, and close to the Damúda River, is the mine of Rogonáthchuk, the property of Messrs. Erskine and Co., no out-crop is seen, as it is concealed by the alluvium of the river. The seam dips North at an angle of about 3°, and has the following section :—

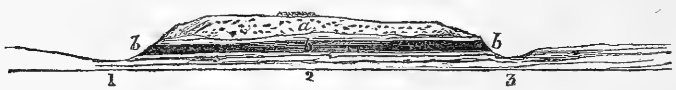
	Ft.	in.
Coarse sandstone.		
Coal	6	0
Shale	0	6
Coal	5	0
Total thickness of seam ...	11	6
Coal in ditto	11	0

This seam, like Rániganj and Mangalpúr, is intersected by a trap dyke, South of which the coal has been exhausted, and the mine abandoned. The depth of the two shafts at present worked is 138 and 148 feet. The West of the colliery is bounded by a fault, the down-throw of which is unknown, and beyond which the seam has not been found. It is evident that neither the section, nor the probable relations of the coal seam give the slightest clue to the elucidation of the seams of Rániganj and Sirsol.

Damúlia Colliery.

But West of Rániganj it is different. Beyond the faults bounding the colliery all the Northerly dips disappear, and the rocks come in with a steady South dip averaging about 3° or 4.° South of the Núnia, coal is found underlying the village of Damúlia, and, although thrown by several small faults, the seam appears to underlie the greater portion of the alluvium and gravel between the Núnia and the Damúda, on the banks of both of which it crops out in places. Being so close to the surface, the coal is of course inferior and somewhat decomposed. It is, however, worked to a considerable extent, and its section is as follows:—

FIG. 7. SKETCH SECTION OF THE DAMULIA COAL.



a, gravel—*b*, coal seam.

1. Damúda River. 2. Damúlia village. 3. Núnia River.

			Ft.	in.
a.	Shale	... ...	0	0
b.	*Coal*	... ...	6	0
	Ironstone	... ...	0	1
	Coal	... ...	3	0
c.	Shale	... ...	0	1
d.	Coal	... ...	0	9
e.	Shale	... ...	0	3
f.	Coal	... ...	6	0
		Total thickness of seam ...	16	2
		Coal in ditto	15	9

The quarries are situated just North of the village of Damúlia, and North-east of Harábhánga. But the seam has also been worked E. S. E. of Damúlia, and is seen South of the village, while it is stated that a pit sunk (by Mr. Jackson) in the bed of the Damúda also proved its existence, so that it probably underlies a considerable

proportion of the tracts here covered by alluvium. It is difficult to say how far it extends East. It is extremely probable that it would be found South of the Damúda if sunk for West of the place where the Músúria stream runs into the Damúda, about a mile West of Adgaon.

There can be little doubt that the seam is identical with that of Rániganj. The only difference is the thickening of the lower portion, probably at the expense of the shale below.

Beneath this seam comes coarse sandstone, probably not above 50 feet thick, and then the following section, at the place where the stream running from the North of Morgáthi joins the Núnia.

	Ft.	*in.*	
Coarse felspathic sandstone, speckled white and brown	30	to	40 feet seen.
Blue clay, shale and strings of *coal*	2	3	
Coal (good apparently)	2	0	
Blue shale	0	6	
Coal	0	3	
Blue shale, about	2	0	
Micaceous shaley sandstone and shale	7	6	
Fine sandstone	4	0	
Blue shale	0	6	
Carbonaceous thin-bedded sandstone	0	4	
Blue shale	4	1	
Ironstone	0	1	to 0 5
Shale	0	10	
Ironstone, sandy	0	2	
Carbonaceous shale and strings of *coal*	0	4	
Blue sandy shale	4	6	
Clay shale	0	4	
Carbonaceous shale, with *coal*, and irregular bands of sandstone	3	0	
Sandy shale and irregular bands of sandstone ...	0	0	

These beds, with the interstratified coal and carbonaceous shale, appear to occupy the place of the Narrainkúri coal seam. They are traced West about a mile as far as a sharp bend of the Núnia, North-east of Theraut, and to the East they wind among the rocky valleys between Morgáthi and Rániganj, and are traced up the valley West of

Sirsol, but outside the fault running up the valley. The possibility of tracing them, however, proves that no great fault intervenes between that immediately West of Rániganj and Sirsol, and the quarries at Jemeri. There is not the slightest indication of any East and West fault in this patch of ground.

Jemeri Colliery.

The section continues therefore regularly to Jemeri, where a fine seam of coal offers the following section:—

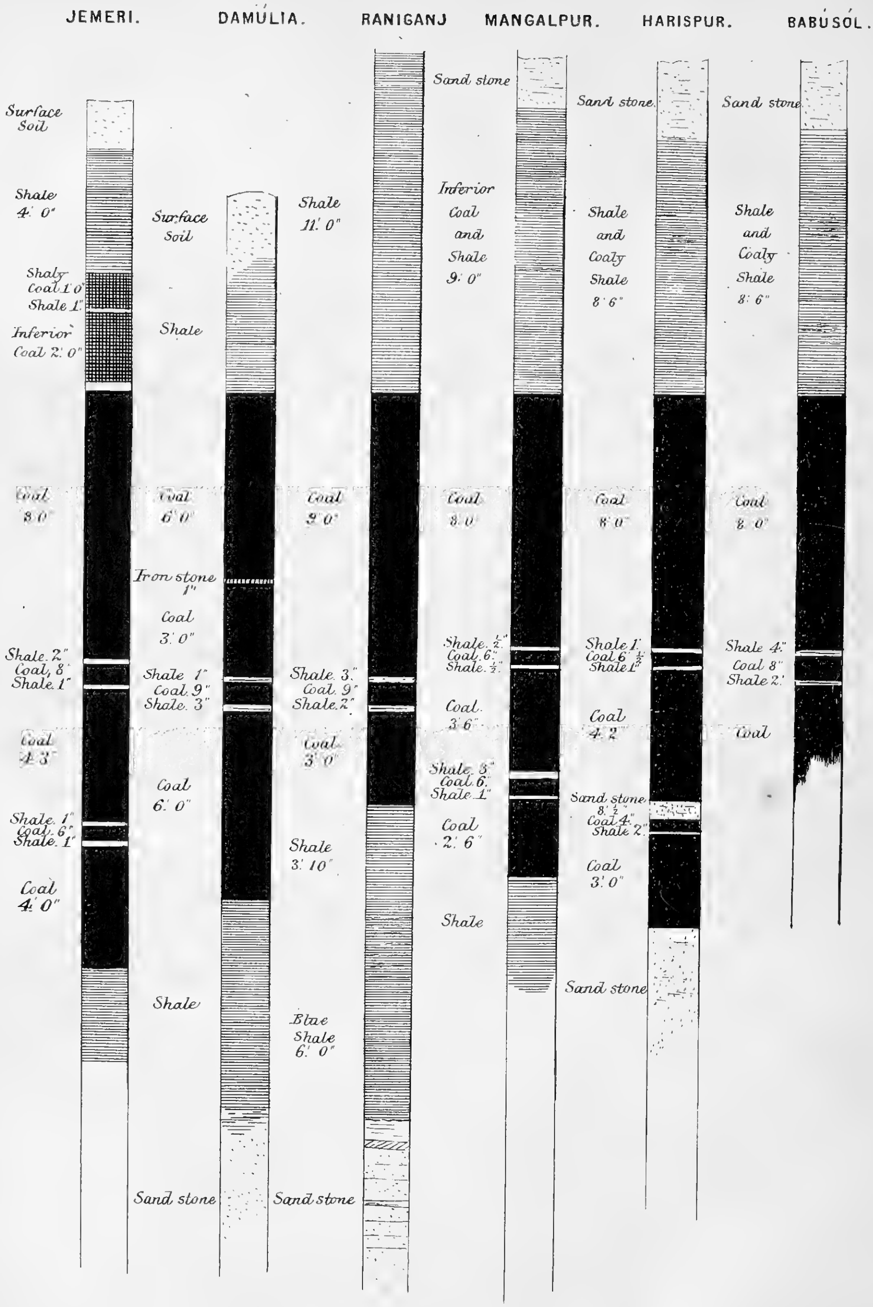
		Ft.	in.
	Sandstone.		
a.	Carbonaceous shale, variable in thickness, from 1 foot to 6 or 8, average about	4	0
	Shaley *coal*	1	0
	Shale	0	1
	Coal, inferior and shaley...	2	0
	Shale	0	3
b.	*Coal* of excellent quality	8	6
c.	Shale	0	2
d.	*Coal*	0	8
e.	Shale	0	1
f.	*Coal*	4	3
g.	Shale	0	1
h.	Carbonaceous shale and inferior *coal*	0	6
i.	Shale	0	1
j.	*Coal*, 3 or	4	0
	Total thickness of seam	25	8
	Coal in ditto	20	5

If now we proceed to the comparison of this seam with the various seams of Damúlia, Rániganj, Mangalpúr, Harispúr, and Bábúsol, we shall see that in every one of these seams there is,

a. A bed of carbonaceous shale, varying from 8 to 1 foot in thickness.

b. Good coal, 8 or 9 feet thick, in one instance (Dámúlia) with a thin parting of ironstone.

c. Shale parting from ½ inch to 3 inches.



COMPARATIVE SECTIONS OF COAL SEAMS NEAR

RANIGANJ.

SCALE ONE INCH = 6 FEET.

DRAWN ON STONE BY RUMANATH DASS, AND LITH: BY H.M. SMITH, SURV GENL'S OFFICE, CALCUTTA, 1861

d. A thin bed of coal, 6 to 9 inches thick.

e. A second narrow shale parting.

f. A bed of coal 3 feet to 6 feet. This differs slightly in thickness, more so than any of the others.

But beneath this there is a wide distinction between the seams.

Comparison of sections.

In Ránigan and Damúlia no more coal is found; in Jemeri, Harispúr, and Mangalpúr there are two more seams of coal, and two shale partings. Still there is nothing improbable in this amount of difference being shown by a seam of coal within a few miles, and there would be on this score no difficulty in believing that all of the seams were identical. But it is evident that the Jemeri seam is far lower in the section than the Damúlia seam. Equally clear that the Damúlia seam is identical with that of Ránigan, and there can be no question that, judging from the astonishing exactitude of the sections, the Mangalpúr bed is far more likely to be the same as that of Jemeri than as that at Ránigan. (See comparative Sections.)

Again, as regards the Sirsol seam, it appears that, in a considerable series of beds, underlying the Ránigan seam, we have no representative of it. The only bed of coal of any thickness is that of Jemeri, and it, instead of corresponding to the section at the neighboring colliery of Sirsol, answers to that at the far more distant mine of Mangalpúr. We are therefore driven to the conclusion that the Sirsol seam is higher than that of Ránigan, unless, as is improbable, it be identical.*

The principal fault West of Ránigan must therefore be continued up the valley, West of Sirsol, and it must there be of very considerable dimensions. There is, in all probability, only a small fault between the collieries of Ránigan and Sirsol.

* If the lower parting of shale in the Ránigan seam were wanting, its section would be nearly identical with that of Sirsol. But these small partings seem singularly persistent. There is, of course, a possibility that the seams may be the same, but it is not very likely.

To recapitulate. There are, in the Rániganj area, three principal seams of excellent coal. The highest of these, 17½ feet thick, is worked at Sirsol only, and is unknown elsewhere. The second, about 250 feet lower in the section, and 13 feet to 16 feet thick, is found and worked at Rániganj and Damúlia, and probably underlies a considerable tract North of Rániganj, including the station, and a third seam 15 to 20 feet thick worked at Jemeri, Mangalpúr, Harispúr, Bábúsol, and perhaps at Parasia.

But these conclusions may be fallacious. There can be very little doubt that the Mangalpúr, Harispúr, and Bábúsol seams are the same, but their close representation by the Jemeri seam may be accidental.*

Several quarries are worked in the Jemeri seam, within the village lands, by Bábú Gobind Persad, the owner of Sirsol, and a mine has been commenced upon the same seam, in the adjoining village of Nimcha, by the Bengal Coal Company. The coal from the main seam is of excellent quality, and, probably, when mined from a sufficient depth to be beyond the range of the decomposing action of surface waters, will be found equal to that of Sirsol, if not even better. The out-crop cannot be traced for any distance to the West, but it is seen running in a direction of East 10-20° West for nearly a mile, as far as the village of Nimcha.

The backs in Rániganj mine are North 25° East and West 20° North, a less marked one being W. S. W.; in Rogonáthchuk they are West 40° North and North 10° East; in Jemeri North 30-35° East and North 10° West.

Rocks associated with coal.

The rocks associated with these coal seams are, in general, very thick, massive, and rather coarse-grained felspathic sandstones, excessively false-bedded, and occasionally with extremely hard, nodular bands, which are calcareous.

* Should the seams prove as surmised above, the Tapassi or Chokidánga seam may represent that of Banáli. But this is very doubtful.

Some shales occur, but they are of no great thickness. Faults are generally marked by the prevalence of "kunkur" along them.

Banáli seam.

Three miles North of Jemeri, and beyond the Grand Trunk Road, a coal seam has recently been discovered by boring in the land of the village of Banáli, and workings upon it have been commenced by Messrs. Erskine and Co. The dip is South about 30°, and the thickness of the seam is said to be 12 feet. The out-crop crosses the valley lying West of the village of Sathgram. This is an instance of what is, doubtless, common, viz. a coal seam, the out-crop of which is concealed by alluvium, and which can, consequently, only be detected by boring.

IV. *Núnia Valley, East Division.*

This area comprises but few mines of importance, and, owing to the distance of a considerable portion of it from all carriage, whether by river or railway, it has never probably received the attention which has been given to Rániganj and the Singáran valley. It contains, however, some valuable coal seams, comprised within a tract bounded on the East by the water-shed of the Núnia and Singáran, that is, the neighborhood of the villages of Táltur, Núndi, Akalpúr, &c., and by the Rániganj area, just described, and on the West by a line drawn North and South through Asansol.

Beds at base.

Commencing, as usual, from the base of the beds, the lowest rocks met with are the same fine sandstones, with occasional hard bands as occur further East. But very few sections are seen, the best being South of Púchra, in streams running into the central branch of the Núnia. The mass of the rocks seen are the usual massive, false-bedded sandstones, white or brownish,

seldom very coarse, and almost always abounding in felspar. The only seam of coal known to occur is that worked near Charnpúr and at Samsundarpúr, by Messrs. Apcar and Co., and by a native, respectively. The seam is 13 feet thick, of which 12 are worked, and the coal is of fair quality. The workings are not extensive, but the out-crop has been cut into to a considerable extent from quarries.

Charnpúr and Samsundarpúr.

About 2 miles W. N. W. of these collieries, on the line of strike of the beds, a quarry has been opened close to the village of Baraboni, on the property of the Ráni Srinamoni. The seam is 17 feet thick, and the coal unusually bright and excellent in quality, but it contains much pyrites. The "backs" head N. 10° E., but for want of cross jointing, the coal cuts badly. It is very possibly the same seam as that worked at Charnpúr, and, if so, should be sought for South of Domaháni.

Baraboni.

Nothing except the usual coarse sandstone is seen above these seams, till near Puriharpúr, on the Eastern stream. Here a quarry, with under-ground workings, extending to a considerable distance, has been worked for three years by the Bengal Coal Company, in a 9 feet seam of coal of fair quality. The seam dips to the South-west about 3°.

Puriharpúr.

No more is seen in the Eastern branch of the Núnia till near its junction with the main stream. On the latter coal is worked by Bábú Debhidin Súkal, about 1 mile South of Madanmonpúr, at a spot called Mainanagar. The seam has the following section:—

Mainanagar.

	Ft.	in.
Hard blue shale, with nodules of clay ironstone.		
Coal	5	0
Shale	0	9
Coal	4	6
Total thickness of seam ...	10	3
Coal in ditto	9	6

The coal is of good quality. Not many feet lower is a second seam, which has also been quarried close to the Núnia, but which is, where exposed by the stream, so cut up by trap as to be worthless. These seams must be much higher in the series than that of Puriharpúr. The Mainanagar seam is now being worked by Messrs. Erskine and Co. on the right (West) bank of the Núnia, at Dadkia.

Blue micaceous shales and felspathic sandstones, all dipping steadily to the South-west, follow, and contain one seam of coal 2 feet thick, but the higher series of the Panchét beds come in on the Núnia, about half a mile South of Mainanagar. The stream, for some distance, continues along their strike, and just inside their boundary, until it turns sharply to the East, about due North of Asansol, exposing flaggy sandstones dipping to the West. Near to the spot where a rather large trap dyke crosses the stream, a seam of coal 4 feet 6 inches to 5 feet thick is seen, in which a small mine is worked by Messrs. Acland and Co., at Sáth Pokaria. The coal is of excellent quality, probably surpassed by none in the field. The roof in this case, as in many others, is coarse, hard sandstone.

A little further East, the Western and Central branches of the Núnia join, and not far below the seam last mentioned, the following section occurs:—

	Ft.	*in.*
Coarse felspathic sandstone ... ... 50 or 60	feet	seen.
Shale and shaley sandstone	5	0
Coal	0	3
Shale and thin sandstone alternating, and containing fossil plants ...	3	0
Fine gray sandstone...	1	0
Carbonaceous shale and *coal*	0	3
Shale and shaley sandstone alternating...	6	0
Blue sandy shale	3	0
Thin-bedded sandstone	1	6
Carbonaceous shale	0	8

O

			Ft.	in.
Coal	1	8		
Carbonaceous shale	0	10		
Coal	0	4		
Blue and carbonaceous shale	0	6		
Coal, shaley, in parts	1	0		
			4	4
Very fine blue and gray sandy shale			4	0
Ditto coarser, with bands of fine, hard calcareous sandstone ...			10	0
Coal and carbonaceous shale			3	0
Shale, carbonaceous, in parts			0	8
Sandstone, in thin beds			0	4

Beneath the above come some hundreds of feet of coarse, yellowish-brown felspathic sandstone, containing mica, with a few shaley beds, and a thin seam of coal near the base; but the section is not good enough for measurement. Below these are :—

				Ft.	in.
	Thin sandstone and shale, about			40	0
	Hard, blue shale	10	0		
Gúshin and Asansol seam	*Coal*	1	0		
	Shale	0	6		
	Coal	7	0		
	Total thickness of seam ...			8	6
	Coal in ditto			8	0
	Coarse sandstone			80 to 100	
Ninga seam	*Coal*	2	10		
	Shale	0	2		
	Coal	1	1		
	Shale	0	1		
	Coal	1	10		
	Blue shale	0	4		
	Coal	0	11		
	Total thickness of seam ...			7	3
	Coal in ditto			6	8

The two lower seams occur close to the spot where the Grand Trunk Road is carried across the Núnia by a suspension bridge. The beds here dip W. N. W., the strike being nearly parallel with the

general direction of the Núnia, which, consequently, crosses their out-crop repeatedly. That of the higher seam is first crossed about 200 yards above the suspension bridge, and North of the Grand Trunk Road; that of the lower seam about the same distance South of the bridge. The uppermost is worked at Asansol colliery, just North of the road, by Bábú Ramanáth Banerji, and in some small quarries, South of the road, by Bábú Gobind Parsád, at Gúshin. Nearly opposite Bábú Ramanáth's quarry, and on the East bank of the stream, another has been made by a different proprietor, but it is not worked.

Coal near Asansol.

This seam crosses the Núnia again three times below the bridge, the two lowest crossings being close together, where an angle in the stream has cut into the out-crop of the bed. Here some quarries have been worked by Messrs. Tárachander Pál and Co. The section is nearly the same as North of the bridge, being

Núnia section, South of Trunk Road.

	Ft.	in.
Blue and carbonaceous shale.		
Coal and shale mixed	0	6
Coal	1	0
Carbonaceous shale	0	4
Ditto, with coal	0	4
Coal	6	0
Total thickness of seam ...	8	2
Coal in ditto	7	0

The dip is throughout small, but somewhat variable, and inclined near the bridge to the W. S. W.: further down to South-west. The coal is inferior.

The lower seam, also about 7 feet in thickness, has been cut into North of the Grand Trunk Road, by Bábú Rákal Dás, in the village land of Sripúr. The out-crop crosses the Eastern branch of the Núnia, which here joins the main stream, but further North and North-west all trace of it is lost.

From the Sripúr quarry scarcely any coal has been extracted, but South of the road some large quarries have been worked by Bábú Gobind Parsád. The coal is of fair quality, far superior to that in the upper seam. A mine has been commenced near this by the East India Coal Company, upon the same seam, but no coal has as yet been extracted.

These two seams, doubtless, underlie all the ground West of the Núnia at no great depth, and as the new line of railway will pass close to their out-crop, they may probably hereafter be largely worked in the villages of Asansol, Múslia, Gúshin, &c. The out-crop of the lower and superior seam probably passes S. S. E. through the villages of Mahántur and Rotibati.

West of the Núnia, at least 200 or 300 feet above the coal seams last described, there is a run of carbonaceous shales and ironstones, the latter thin, but of fair quality. These may represent a bed to be hereafter described, as having a considerable extension to the West of the basin of Panchét beds, which occupies so large a portion of the area West of the Núnia, between the Grand Trunk Road and the River Damúda. Above these shales again, and close to the great trap dyke, which runs, bearing North 20° West, through the village of Dhámra, the out-crop of a coal seam is exposed a little South of the small stream which crosses the dyke South of the Grand Trunk Road.

Near Kumárdhi at Chalwad.

Below Rotibáti, a burnt out-crop of coal is seen in the Núniá, opposite the village of Kumárdhi, and thence for a considerable distance, the stream runs through coarse felspathic sandstones, and mostly along their strike. A coal seam, intersected by trap, crosses the stream about three-quarters of a mile East of the village of Chalwad (or Chalwidi), and has been worked by Bábú Gobind Parsád, in Chalbalpúr, East of the Núnia, and by the Bengal Coal Company, to the West of the stream (Beldánga).

The section is :—

			Ft.	in.
Shale			6	0
Coal	4	6		
Shale	0	2		
Coal	4	6		
Total thickness of seam ...			9	2
Coal in ditto			9	0

The dip is at a low angle to S. S. W. Below this, nothing but sandstone is seen in the Núnia, as far as the section already described, as occurring North of Harabhánga.

Coal South of Dhámra unworked.

The high ground on which stand the villages of Dhámra and Chalwad is, as usual, covered by alluvium. South of it, on the banks of the Damúda, massive sandstones and some shales are seen dipping to the South-west. About half a mile West of the great Sálma dyke, already mentioned as passing through Dhámra, a bed of coal is seen, 8 or 9 feet thick; its out-crop being shown on the bank of the River Damúda. It is extraordinary that this seam, thus visible upon the bank of the river itself, has never been worked; considering the unusual facilities afforded by its place of occurrence for the carriage of any coal mined from it to markets; and especially as, until within the last few years, the only mode of carriage to Calcutta was by the river. It is difficult to judge from merely seeing the out-crop of a seam, whether the coal contained is of good quality or not; that of this seam, however, appears to be fair coal, and no trace of any excavation is visible in the neighborhood, so that I have not been able to come to any other conclusion than that it has never been cut into. Yet within half a mile coal, which had been brought from beyond Dhámra, has been piled at a ghât for shipment.

V. *Núnia Valley, West Division.*

This embraces all the area occupied by the Rániganj beds North of the Grand Trunk Road, and not already described. It is a small district, comprising only the mines of Sitarámpúr, Damúda, Fatipúr, and Gharwi. So much of the ground as lies between the Central and Western branches of the Núnia is covered with alluvium, all void of sections, and completely unexplored by means of borings and sinking. There can, however, be little doubt that it is underlaid, in part at least, by the seams now to be described, as seen in the section afforded by the West branch of the Núnia.

Diminution in coal to West and South.

This section is, perhaps, on the whole, the best and most continuous seen in the Rániganj series. The higher beds of that series are, in all probability, wanting, and the coal seams are, in general, thinner and fewer than those which occur about Rániganj and on the Singáran. There appears to be a very great diminution in the size of the seams generally towards the West and South, a circumstance which will be further illustrated in the discussion of the beds occurring South of the Damúda.

Section in Núnia.

Commencing on the top of the ironstone shales, near the village of Malakola, the first beds seen are the usual slightly sandy carbonaceous shales. Upon these come, all regularly dipping at about 15° to the S. S. E., the following beds :—

1. Rather fine somewhat felspathic sandstone, a few massive bands occur, but the rock in general is thinly bedded and soft.
2. Fine thin-bedded micaceous sandstone, with hard, yellow calcareous bands and nodules.
3. Ditto, rather coarser.
4. Carbonaceous, shaley sandstone, and shale.
5. Fine muddy shales, with numerous fossil plants well preserved.
6. Fine, brown micaceous sandstone, carbonaceous in parts, with bands of hard, nodular, calcareous rock.
7. Carbonaceous shales and ironstone.
8. Ditto and sandstone.

9. Massive felspathic sandstone, with calcareous bands.
10. *Coal* worked at Sitarámpúr.
11. Fine bedded sandstone, felspathic, brownish-gray, and carbonaceous, some lenticular hard bands and some muddy shale.
12. Ditto coarser, a small seam of coal 1 foot thick is seen here.
13. *Coal*, 6 feet.
14. Sandstone as before.
15. *Coal*, 12 feet.

Sitarámpúr colliery.

The above embrace a thickness of nearly 3,000 feet, and comprise three worked seams of coal, the lowest being that mined by Messrs. Apcar and Co., at Sitarámpúr. It is said to be of excellent quality, but in consequence of the engine on the works being too small for the mine, no coal was extracted during the years 1859 and 1860, and, consequently, the workings were full of water. The out-crop has been largely worked, the thickness of the seam is said to be 12 feet.

Messrs. Apcar's colliery upon this coal seam is to the West of the Núnia: East of the stream some quarries have also been worked by the Ráni Srinamoni, but they are small. The two higher seams enumerated in the above section have been, to some extent, worked by the same proprietor, especially the upper one, which is quarried in land belonging to the village of Dhámra, and the coal in which is of good quality. It is overlaid by shales, containing fine impressions of fossil plants.

Rogonáthbati.

Two hundred or three hundred feet above the last mentioned coal, is a seam, probably about 5 feet thick, and upon which some small quarries have been dug. It is about to be worked by Messrs. Apcar and Co., near Rogonáthbati.

Gharwi : Barachuk.

The next seam seen is worked by Messrs. Apcar and Co., at Gharwi, North of the Núnia, (which here runs from West to East,) and at Barachuk, South of the stream : until lately the workings at both these places have been merely

quarries. More recently, however, shafts have been sunk at Barachuk. The section of the seam is

	Ft.	in.
Sandy shale and thin sandstone.		
Coal	3	8
Shale	0	4
Coal	6	4
Thickness of seam... ...	10	4
Coal in ditto	10	0

The dip is South 35° East, about 8°, and throughout this portion of the section it never exceeds 10°. The rocks are a succession of ordinary felspathic sandstones, with frequent interstratifications of finer sandstones and shales, the latter frequently fossiliferous.

Fatipúr.

The Barachuk seam is also worked at Fatipúr, nearly a mile further West and on the Grand Trunk Road, the shafts being about 90 feet deep. The whole thickness of the seam here is said to be 12 feet, but there can be very little doubt of its identity with that mined at Barachuk.

Two more seams, each about 5 feet in thickness, occur above the last-named, and their out-crop is seen in the Núnia, about half a mile from each other, North of Kumárpúr. Both have been worked slightly by Bábú Debhidin Súkal, of Majuri, but the quarries have been abandoned for three or four years. Not far above the highest of these seams, *Panchét* beds come in unconformably in the stream.

Small quantity of coal in this section.

It is probable that but few more coal seams exist in this locality, besides those described above. Their aggregate thickness amounts to only 58 feet, a very much smaller quantity than that known to exist in the Singáran valley, and about Rániganj. Doubtless, the uppermost beds, which contain all the finest seams, are wanting in the Núnia, having been removed by denudation previously to the deposition of the Panchét beds, which

here overlap very considerably. Indeed, it appears probable that the Núnia section includes a smaller thickness of rocks than occur any where else in the Rániganj series, in consequence of the absence of all the highest beds. But even allowing for this, there does not appear to be the same abundance of coal in this part of the field as further East, and the seams which occur are thinner.

VI. *Chinakúri and its neighborhood, with the country West, as far as the Barákar River.*

Hatinal.

By reference to the map, it will be seen that the rocks intersected in the Núnia, near Sitarámpúr, Gharwi, &c., strike across to the W. S. W., and are again exposed in the Hurál, a stream running into the Damúda, West of Chinakúri. No section is seen at the base of the series, the rocks near which crop out, however, near Jassaidhi, in one or two places, and consist, as elsewhere, of thin micaceous sandstones, with hard, somewhat calcareous bands. South of this, at Hatinal, and about 600 or 700 feet above the ironstone shales, a coal seam is worked, which gives the following section:—

	Ft.	in.
Shale.		
Carbonaceous ditto	0	3
Coal	1	2
Shale	0	1
Coal	0	9
Shale	0	2
Coal	6	0
Total thickness of seam ...	8	5
Coal in ditto	7	11

The partings, however, are not constant throughout the workings.

The principal backs run North 15° East; and smaller ones strike West 40° North, and North 35° West. The mine has not been long worked. The coal is of fair quality.

Deziragarh.

About a mile E. S. E., from Hatinal colliery, a seam crops out in the bed of a small stream South-west of Deziragarh. It was formerly worked by Messrs. Carr, Tagore and Co., but the quarries have fallen in; the thickness of the seam cannot be distinguished ; it is probably from 5 to 6 feet.

East of this, and near the river, in the broken ground South of the village of Shatulpúr, two or three out-crops are seen, but the whole section is best exposed in the Húrál, commencing about due West of the village of Rádanagar. The lowest seam of coal seen is 5 or 6 feet thick apparently, but in this, as in most other cases, the exact dimensions are doubtful.

Section in the Hural stream.

About 150 or 200 feet of sandstone, generally fine and micaceous, in thin beds, with much shale, intervene between this seam and a second, also about 5 feet thick ; 20 feet above the second is a third seam, apparently of good quality, but only 3 or 4 feet thick, and just above the last are two or three very thin seams, not exceeding 1 foot each. The remainder of the section to the place where the stream enters the Damúda, is approximately the following:—

(Ascending.)

		Ft.	*in.*
1.	Coarse false-bedded sandstone, about	50	0
2.	*Coal*	5	0
3.	Sandstone and shale	150	0
4.	*Coal*, thickness not seen	0	0
5.	Sandstone and shale	20	0
6.	*Coal*	2	0
7.	Sandstone	2	0
8.	Shale	1	0
9.	Sandstone	3	0
10.	Shale, carbonaceous, and with some *coal* in the upper portion ...	3	0
11.	Hard sandstone	2	6

	Ft.	in.
12. Sandstone and shale, with strings of coal	20	0
13. *Coal*	1	0
14. Shale	1	0
15. *Coal*, about	6	0
16. Shale, about	20	0
17. Coarse sandstone	10	0
18. Shale and sandstone, containing a seam of *coal*, 1 foot thick, in the upper portion	10	0
19. Massive sandstone	10	0

Thin sandstones and shales completing the section to the mouth of the stream, which is only a short distance.

There are seen, in this section, 5 seams of coal, exceeding 3 feet in thickness, besides several thinner ones, and others whose dimensions cannot be ascertained. As none have been worked, it is impossible to speak positively of their value. Some may be of rather greater thickness than is above mentioned, as a portion of the out-crop is, in some cases, concealed.

Out-crops near Bághdi.

In the stream between Bághdi and Rádanagar, in two or three places, coal crops out. There is, however, no continuous section, and the thickness of the seams is not seen. They are, doubtless, the same as those in the Hurál Jor.

Old Chinakúri mine.

About a quarter of a mile South-east of the mouth of the Hurál Jor, and close to the village of Chinakúri, is the old Chinakúri mine, worked by Mr. Betts, in the years 1826—1830. The seam is 7 feet thick, and, according to Mr. Williams, has the following section* :—

	Ft.	in.
Coal, inferior	6	0
Carbonaceous shale	0	4
Coal, inferior	1	2
Total thickness of seam ...	7	6
Coal in ditto	7	2

* Report, page 56.

New ditto or Salúnchi.

It is about 80 or 100 feet above the top of the last detailed section. The coal is said to have been very inferior. The seam now worked at the Chinakúri or Salúnchi colliery is 600 or 700 feet higher, and none is known to intervene between the two. The new or Salúnchi seam is altogether 10 feet thick,* but only 7 feet of the upper portion is worked. The section of the old engine shafts is said to be †:—

				Ft.	*in.*
	Surface earth			9	6
1.	Sandstone, decomposed			0	4
2.	Ditto, compact			34	4
3.	Ditto, yielding water			37	8
4.	Micaceous sandstone			10	6
5.	Hard calcareous ditto			9	0
6.	Shale			9	0
7.	*Coal*	7	0		
8.	Shale	0	4		
9.	*Coal*	3	6		
	Total thickness of seam ...			10	10
	Coal in ditto			10	6

The quality is good. The seam has been worked for a distance of at least a mile along the out-crop, to a depth of about 100 or 120 feet. Deeper workings have now been commenced, the coal at a small depth having been nearly exhausted.

The out-crop of this seam probably stretches for 1 or 2 miles to the East, and may perhaps be found just South of the villages of

* This I learn from the section in the possession of the Bengal Coal Company, and which is given below. The lower seam, 3 feet 6 inches thick, is also given in the sections of Messrs. Williams and Homfray, but as it is not worked, no complete section of the seam is exposed, and I have never seen it. It appears to be wanting South of the Damúda, at Hírakúnd.

† About 50 feet above the Chinakúri seam, a bed of coal, about 1 foot thick, occurs, which is omitted in this section. It is seen in the stream West of the colliery, and was found in sinking for the new engine shafts.

Baráchuk and Patmáni, as it is underlaid at a depth of about 300 feet, by a run of carbonaceous shales, with little seams of ironstone. This run can be traced without a break, from South of Maitani to near Chinakúri village, and recurs South of the Damúda. It appears to be concealed by alluvium close to Chinakúri village.

Extension of seam East and West.

Probably the coal seam is overlapped by the base of the Panchét beds near Patmáni: the ironstone and shale disappearing, doubtless, from the same cause, somewhat further East, near Digari; and appearing to be faulted near the spot where it is overlapped; but this is doubtful.

To the West the Chinakúri seam has not been traced beyond the brook West of the colliery, and it is stated that Mr. Betts bored to a depth of 250 feet, without finding coal. No fault, however, can be made out to occur, and very little dependence can be placed upon reports of borings, the exact locality of which is not known. They may have been outside the out-crop: still it is quite possible that a fault exists.

No rocks are seen for some distance above the Chinakúri coal seam, which does not appear to be more than 200 or 300 feet below the base of the Panchét beds.

VII. *Country South of the Damúda.*

West of the Barákar, and North of the Damúda, no rocks are seen in the small area of Ràniganj beds which are found there. The rocky island at the mouth of the Barákar is entirely composed of sandstone.

The description of the beds South of the Damúda will commence most conveniently in the neighborhood of those last alluded to, and, consequently, from the West, where alone, on the right bank of the river, the lowest beds of the Rániganj series are met with. The two large faults, one passing by Chánch, and the other down the Barákar, are not clearly traced to the

Chánch and Barákar faults.

South. The latter is, doubtless, cut off by the former,* and as much breaking and disturbance is seen in the rocks around Deoli, it is probable that the Chánch fault crosses the river there. No probable direction is shown in the map, but, as in many other cases, there is an apparent diminution in the amount of throw towards the South, which may possibly be due to these faults having been partly, but not entirely, formed after the deposition of the Lower Damúdas, and before that of the Ràniganj series. They would consequently have a much greater throw in the former than in the latter beds. But it is not probable that the unconformity between the two series is so great as the existence of much disturbance during the intervening period would imply.

Beds South of Koelasota.

Upon the thin ironstone shales, South of the village of Koelasota, rather coarser carbonaceous shales, with bands of calcareous sandstone, and, towards the base, runs of sandy black band, rest as usual. These beds are well exposed North-west of the village of Núdia. The dip is high, owing, doubtless, to the rapid twist of the strike, and the neighborhood of great faults to the West and the North-east. The lowest coal seams seen are in the stream between Narrainpúr and Barshádhi, where a small bed occurs about a foot thick, and 100 feet above that a second, apparently 6 or 8 feet thick, in the out-crop of which a small quarry was opened by the Bengal Coal Company, but the coal, being found to be of inferior quality, was not worked. Two hundred or two hundred and fifty feet higher, is the seam formerly worked by the Bengal Coal Company, at Núdia; the section of which is thus detailed by Mr. Williams†:—

Seams near Narrainpúr.

And Núdia.

	Ft.	in.
Brown gray sandstone	21	0

* The continuation of the Barákar faults is probably that forming the West boundary of the field from the Damúda to Panchét Hills.

† Report, page 60.

	Ft.	in.
Coal, of good quality	9	7
Black carbonaceous shale	1	0
Coal, superior	2	0
Gray under-bed	3	0
Brown and gray sandstone.		
Total thickness of seam ...	12	7
Coal in ditto	11	7

Mr. Williams also considers the quality as superior to the coal of Rániganj, Chinakúri, Chokidánga, Dhosúl, and Mangalpúr. As the mine has now been abandoned for many years, and the out-crop is concealed by rubbish, it is impossible to do more than quote the above.

Ironstone shales.

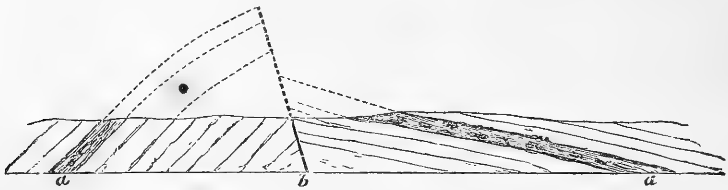
The beds above this are ill seen, the country exposing no sections till within about a mile of Panchét Hill. Here the small bed of carbonaceous shales, with runs of ironstone, is met with, which was observed North of Chinakúri. It here also is at about the same depth below the base of the Panchét beds, or perhaps rather more, *viz.* about 900 feet. Near Chinakúri the depth probably is about 700 feet.

This run of ironstones and shales is traced from near Hirakúnd, opposite Chinakúri, through Luada and Bara, till cut off by a fault near Chándidhi; it is again seen near Nautundhi, and also, in precisely the same position in the general section, near the base of Panchét Hill; disappearing, however, probably from having thinned out, on the West side. It also stretches across from North of Panchét to North of Garangi Hill, and altogether its out-crop has been traced for not less than 15 miles South of the Damúda. It thus becomes a very constant and important horizon, and serves to prove the absence of faults crossing the direction of its strike, while, on the other hand, it gives the best evidence obtainable of the existence of a great line of fault, probably in continuation of the Chánch fault, but in a direction more nearly approaching East and West; for the run of ironstones comes in, *with*

Fault North of Marúlia.

a low dip, (see Fig. 8) at a much shorter distance North of the anticlinal,

FIG. 8. SECTION OF ANTICLINAL AND FAULT NEAR MARULIA.



a a. Ironstone shales. *b.* Fault.

near Marúlia, than it does among the higher dips to the South.

East of the area occupied by the Panchét beds, North of Behárináth Hill, these ironstones do not recur. The best section of them is seen in the Besram stream, close to Madúwanpúr. They are here, with the accompanying shales, about 25 to 30 feet thick, the proportion of ironstone, of excellent quality, being larger than is usual in any part of the great band at the base of the Ràniganj series. Situated as the out-crop of this band is, at a distance from other sources of ironstone, it may hereafter be worth working for ore, and, in the prospect of such an occurrence, and of its becoming of economical value, the out-crop has been laid down carefully on the map.

Beds near Panchét Hill.

To the West and North-west of Panchét Hill, the beds of the Ràniganj series dip at very high angles, and are much compressed and disturbed. No coal is seen. All the beds twist sharply round to the South-west, and are cut off, as are the lower series also, by the fault West of Bághmára. It is not clear where the Panchét rocks come in, the neighborhood of the boundary being much broken and confused, but the whole of the hill is composed of rocks higher than the Damúda series.

Coal near Deoli.

A very little West of the spot where the Barákar joins the Damúda, and upon the South bank of the last-named stream, a rocky promontory projects into the river near Deoli. In this a seam of coal, about 4½ feet thick, is seen, with

sandstone both above and below. The seam thins out and disappears about 150 yards to the West of the place, where a mine has been commenced upon it by the Bengal Coal Company. A fault is seen to the South-west, and, probably, cuts the seam off in that direction.

Coal near Hijali.

In the stream just West of the village of Hijali, three or four seams of coal are seen, the lowest and thickest of which is about 4 feet, the others 2 feet to 3 feet thick. Passing further East, and higher in the series, North of Párbatia, a seam 3½ feet thick is exposed in the right bank of the Damúda. Passing further down the river, past the run of ironstones, a coal seam, 5½ feet thick, occurs at Hírakúnd; it has been worked within the last few years by the Bengal Coal Company, but is now abandoned. The seam is evidently that of Chinakúri (new mine), here thrown to the South by a fault, with a down-throw to the East, which is seen to form the boundary of the Panchét group for some miles on the East of Hirakúnd. Above it the same 1 foot seam, which occurs also above that at Chinakúri (*see* note page 116), is seen.

Section in Besram stream.

In the Besram stream a fair section is seen, the lowest beds being those exposed near the anticlinal at Marúlia. South of this the rocks dip towards the great fault forming the South boundary; North of it to the basin-shaped depression in the strata occupied by the Panchéts, North of Marúlia, as already mentioned. A large fault, doubtless, crosses, there being not more than 1,000 feet of strata, North of it, below the base of the Panchéts, while there are at least 1,500 to 2,000 feet intervening to the South of it, and further West considerably more.

Coal in the Besram stream.

North of the anticlinal, a seam is seen in the Besram stream, near Ratanpúr. It is only 2 feet thick. North of this, near Alkúsa, several thin beds occur, but none measuring more than from 6 inches to a foot. They are very shaley, and are, in every case, covered by coarse sandstones. At

Khyrbona, in the Besram, a little above its confluence with the Mokhúra or Machkúndona stream, a $3\frac{1}{2}$-feet seam crops out, from which some coal has been extracted by a native. A little North of this is a saline spring, slightly warm, and at this spot, probably, the large fault already mentioned crosses.

Near Marúlia.

North-west of Marúlia, a seam about 5 feet thick was formerly worked by the Bengal Coal Company, and to the South of it, the out-crops of at least twelve other seams are seen in the Besram, none of them exceeding 3 or 4 feet in thickness. The section is imperfect, and thicker beds may occur, but it is a remarkable fact, that, throughout all this area, no seam is known to exceed 5 or 6 feet in thickness, and by far the larger number are below 3 feet.

In the Machkúndona.

In the Machkúndona, South of Marúlia, only four or five seams are seen on the same strike as the more numerous beds in the Besram; one has been a little worked, and has produced good coal, but the thickness is only $2\frac{1}{2}$ feet. It is evident that all the coal seams in this part of the field are exceedingly thin.

From Marúlia to Behárináth few beds are seen, sections being scarce and imperfect when met with. Two thin seams of coal, and a thicker bed of a mixture of coal and carbonaceous shale, are exposed in the stream which runs between Hádhi and Nautundhi.

Coal near Chakbaga.

In the Tintúliarak stream, North of Chakbaga, only one seam is cut through, and this, like those already mentioned, is a thin bed, totally useless economically. This bed is close to the top of the Ráníganj series, and rests on thick conglomerate beds, with grey muddy shales, the former unusual above the Lower Damúdas. The beds dip to three sides, North, East, and South, from near Dúmradhi, and North of Chakbaga a large fault crosses the stream. South of this, and close to the boundary of the field, four seams of coal are intersected by the stream. They dip at very

high angles, the highest is 1 foot thick, and rests upon about 5 feet of sandstone, below which the second, 5 feet thick, occurs; the third is 20 feet lower, and measures 3 feet, and the fourth, 30 feet lower, 6 feet. On the second and third small quarries have been dug, and shafts were sunk to cut them by the Bengal Coal Company, but, by some mistake, they were commenced outside the out-crop of the coal. In consequence of the vicinity of the great faults forming the Southern boundary of the field, and the consequent disturbed and broken condition of the beds, it is in the last degree improbable that any workable coal will be found in this locality. A little fuel may, doubtless, be obtained from irregular workings, but a large mine is out of the question.

North of the fault and opposite to the village of Parabira, a shaft has been sunk to a depth of 86 feet, without any coal being found, a result which might have been anticipated, as a considerably greater thickness of beds than 100 feet are seen dipping South towards the shaft, without the slightest indication of a coal seam.

From this point, near Behárináth Hill, for about 3 miles to the East, all the area South of the Damúda is occupied by the Panchét beds. East of these again a considerable area is occupied by Rániganj beds, but nearly the whole surface being covered with alluvium, which, nearly opposite Rániganj, completely covers up all the rocks, very little is seen of the beds. They are, doubtless, the highest of the series, and may very possibly contain in places useful seams of coal. One is said to occur just East of Barhsál, and an old quarry exists, but nothing can be seen of the bed. A little West of where the Sálma dyke crosses the Damúda, an old shaft exists, which was sunk by Mr. Homfray to a depth of, it is stated, more than 200 feet;* only small seams of coal being met with. A few hundred yards South of this, and near the village of Sahibdánga, an out-crop of a seam, 4 or 5 feet apparently in thickness,

* *Jour. As. Soc. Bengal*, Vol. XI., page 729.

and dipping at a low angle to South 20° West, occurs just West of the Sálma dyke.

Only one other out-crop of coal has been noticed in this part of the country. It occurs just South-east of Kálikapúr. The thickness is not seen. It dips to North 30° West.

Before concluding this account of the beds of the Ràniganj series, a few words upon *the representation in one part of the field by beds in other places* are necessary.

It has already been remarked in the earlier portion of this Report, that the greater flatness of the beds on the East of the field causes them to cover a much wider space on their out-crop than further West. The base of the Ràniganj series is shown throughout on the map, but the general imperfection of sections, and the want, except in the one instance of the ironstone run near Chinakúri and South of the Damúda, of well marked beds, whose out-crop can be traced, renders it very difficult to ascertain how far the higher beds represent each other, especially as faults of large dimensions, running from North to South, confuse and disturb the beds.

An excellent instance of this difficulty has already been given in the comparison instituted between the beds around Ràniganj and Mangalpúr. It is evident that no connected out-crops can be traced in a country, the dislocations of which are so little known. No attempt has therefore been made on the map to show distinct lines of out-crop beyond the points where such are known to occur. Far more extensive workings must take place upon the coal before any such map, showing clearly the relations to each other of all the different seams, and the effects upon each and all of the faults of the district, can possibly be made.

Although to the West mines are so few as scarcely to afford any assistance, still the dip of the rocks being steady, and, on the whole, considerably higher, and there being less thickness of alluvium, the

relations of the different portions of the series are distinct, and may be seen by a glance at the map. The coal seams, for instance, about Sítarámpúr, Gharwi, and Fatipúr, on the West branch of the Núnia, are evidently continuations of those seen in the Húral Jor, and their extension occurs in places around Shatalpúr and Deziragarh, and South of the Damúda, for the faults which occur are insufficient to produce any great difference. It is impossible, without either under-ground workings or far more numerous and more perfect surface sections than exist, to identify particular seams at a distance of 5 or 6 miles, but it is clear that the beds accompanying the coal are continuous, and strike steadily across. There is by no means any certainty that the coal seams are continuous over any extensive area. The disappearance, throughout the West and South of all the thick seams so conspicuous, not only around Rániganj, but also in the Singáran, renders it improbable that such is the case. The Chinakúri seam, South of the river at Hírakúnd, is but little more than half the thickness it attains at Salúnchi, and it seems totally to disappear further South, as no similar seam is seen in the Besram stream. Here, however, many thin seams are found, which are wanting at Chinakúri; the run of ironstone proving the identity of the horizon.

So many large faults cut up the rocks in the neighborhood of the central stream of the Núnia, owing to the sudden twist which there takes place in the strike of the beds, that the strata, which were clearly traced up to that point, become difficult to understand to the East, especially as, beyond this, there are scarcely any good sections. The small ironstone shale band, which was so valuable a guide in the upper part of the series, may perhaps be represented by a thin and rather sandy run, which is seen South of the Grand Trunk Road, just West of the Núnia. In this case, the beds of coal worked near Núnia Bridge are nearly on the same horizon as the *old* Chinakúri seam, the new or Salúnchi seam, if it ever existed here, having been removed

by denudation before the deposition of the Panchét group, as has been the case, to all appearance, further West near Asansol, Gopalpúr, &c. Judging from the general strike of the rocks, the beds of Núnia bridge are about equivalent to those of Mainanagar to the North-west, but to the South-east little more than guesses can be made, as large faults unquestionably come in. But, on the whole, it appears probable that the beds of Jemeri, Rániganj, Sirsol, &c., are higher in the series than those of Núnia bridge—such would certainly be the case if the strike were considered as constant and unaffected by faults.*

In this case they must also have been denuded in the area West of the Núnia, before the deposition of the Panchéts, and they are consequently very closely the equivalents of the beds of Chinakúri. The beds of Tapassi, Chokidanga, &c., on the Singáran, will thus be on nearly the same horizon as those of Núnia bridge, Mainanagar, Gharwi, &c. If this be the case, and it bears every impress of probability, there can be no question that the coal seams of the Rániganj series, although far more constant than those in the Lower Damúda, have not the same general distribution over a wide area, as is generally the case in the deposits of the true Carboniferous age in Europe.

CHAPTER V.—*Panchét Group.*

Unconformity on Damúda rocks.

THE evidence of the unconformity of these beds upon the Damúda rocks has already been alluded to incidentally in the description of the Rániganj series, but it will be well briefly to recapitulate. In no place is it very conspicuous, but it

* The Bhangaband seam may be the same as the lower seam at Núnia bridge, but this is only a possibility.

is shown by the gradual overlapping in several localities of the edges of the beds of the Ráníganj series, which beds appear to have been denuded before the period at which the Panchét group was deposited.

The best marked instance occurs along the North-west boundary of the great spread of Panchét beds, which occupy the centre of the field. The strike of the Ráníganj series, where seen in the Western branch of the Núnia, in the Hurál, near Chinakúri, &c., is about West 10° to 15° South, that of the Panchéts West 20° to 25° South, so that the latter group gradually overlaps the edges of the Damúda beds. The ironstone run, which is marked North of Chinakúri, and is there, as already noticed, 700 feet below the base of the Panchéts, disappears near Digari, and at the Núnia the difference in strike is well seen. Here the thin micaceous grey shales and sandstones, at the base of the Panchét group, are seen to dip 30° or 35° East of South, while the Damúdas beneath them dip not more than 10° East of South, the angle of dip being nearly the same in both cases, *viz.* 10°.

Apparent conformity.

The greater thickness of beds between the band of ironstones and the base of the Panchéts, North of Panchét Hill, than intervenes near Chinakúri, and the probable overlap of the Damúda beds, which occur in the neighborhood of Ráníganj, have also been mentioned. It should, however, be remembered, that there is a very considerable apparent conformity between the two groups, and that, excepting in the section on the banks of the Núnia, the want of it can only be made out by a careful comparison of the rocks of each formation over considerable areas.

Difference in mineral character.

In mineral character there is a wide difference between the two groups. The bands of red clay are as characteristic of the Panchét group as coal and carbonaceous shale are of the Damúda.* These bands vary in thickness from

* Carbonaceous shale is occasionally met with among the Talchir rocks, but it is rare. In the Panchét rocks it has never been seen.

a few inches to 10 or 15 feet, and occasionally contain thin beds of white felspathic sandstone, with mica. The ordinary sandstones, which form the bulk of the Panchét formation, much resemble those in the higher portion of the Ràniganj series, but they are even more false-bedded, the stratification being frequently confused in the most extraordinary manner, and sometimes appearing even contorted. Small rolled pieces of silt occur, and these beds have clearly been deposited by a rapid and shifting current, such as that of a large river. In some respects the Panchét beds re-call the Talchirs; very similar greenish and muddy shales occur in places, and the sandstones, although far coarser than they usually are in the Talchir group, resemble the latter in the circumstance of the large quantity of felspar, which they contain, being in general undecomposed. The sandstones are thus rendered more fusible, and the hardened and semi-fused rocks, at each side of the dykes which traverse these beds, stand up above the decomposed trap between them, and form long wall-like lines stretching across the country, as is well seen between Púsathánpúr, Hirapúr, and the Damúda. The Panchét series throughout is highly micaceous, and some beds occur in it almost solely composed of mica.

Resemblance to Talchir beds.

At the base of this group there is everywhere found about 250 to 300 feet of grey and greenish-grey sandstones and shales, often micaceous, and very thin bedded, resembling strongly the middle beds of the Talchir series, and in some places, almost re-calling the mudstones of that series. These beds are extremely constant, and are well seen wherever the lower beds of the Panchét group are exposed in section. They are succeeded in ascending order by the coarse false-bedded felspathic sandstone, in thick beds, with interstratification of red clays, the typical rocks of the formation. Even when no sections can be seen, the color of the surface soil

Base of group.

Coarse sandstones and red clays.

frequently gives indications of the clays beneath, the color of which is a dark purplish-red, similar to that of the old red sandstone in England. The clay beds vary from 20 feet in thickness downwards.

Clay more abundant near bottom.

The lower 500 or 600 feet of the formation (neglecting the thin sandstones at the base,) contain generally a larger number of beds of clay than the higher portion, in which the sandstones are coarser, and conglomerates occur. The whole thickness of the group certainly exceeds 1,500 feet where fully developed, as at the base of Panchét Hill.

Conglomerates.

In one or two places, along the Southern boundary, thick conglomerates occur in the higher beds of the Panchét group, resembling much those overlying the group. Pieces of carbonaceous shale and coal, doubtless derived from the Damúda group, are seen in some of the sandstones. Just North of the village of Deoli, near Bakúlia, and about quarter of a mile East of the mouth of the Besram stream, a considerable expanse of rocks is exposed in the bed of the Damúda, South of the channel occupied by the water in the dry season, and here a bone bed was found, containing detached, and, frequently, rolled bones, vertebræ, and fragments of jaws with teeth; they are not very abundant, but a considerable number were procured. Some were also found in another spot in the Damúda, a little East of the village of Dikha, and fragments of bone were occasionally met with in other localities. The beds will, probably, if further searched, yield very satisfactory illustrations of the vertebrate fauna of the period.

Bone bed.

Estheria.

In one or two places remains of Estheria, and, perhaps, of one or two other small Entomostraca occurred in the Panchéts. Plant remains are rare, but a considerable quantity were obtained from a fine, rather muddy sandstone,

on the West branch of the Núnia, South of Maitúr. The principal species were of *Sphenopteris, Pecopteris,* and other Ferns, distinct from Damúda forms, but with them, and in far greater abundance than any other form, was preserved the plant (*Schizoneura?*) already mentioned as occurring plentifully in the Rániganj series. No Zamias or Cycads of any kind were met with, but fragments of a true *Tæniopteris* were found.

Plants.

The distribution of the Panchét group is simple. They occupy the hollow formed by the synclinal in the centre of the field. To the South, an anticlinal, least just North of Behárináth, and greater East and West of that point, brings up the Rániganj series. South of this the beds roll over again, and the Panchét rocks are once more brought in at several places, with high dips, close to the South boundary.

Distribution.

A good section of the lowest portion of the Panchét group is seen between the Grand Trunk Road and the Núnia, just West of the 139th milestone from Calcutta, and about 2 miles West of Asansol dâk bungalow, where the lower grey shales are exposed. The best sections of the red clay and coarse sandstone are South of the Damúda, in the ravines and broken ground West of the village of Baspaitáli. A good section also occurs North of the river, in the stream to the West of Púsathánpúr, and the bone bed, as already stated, is exposed on the South of the river, North of Deoli, and just East of the mouth of the Besram stream.

Sections.

(b.) Conglomerates and grits of Panchét, Behárináth, &c.

The higher portions of the large hills of Behárináth and Panchét are composed of rocks, differing considerably, in mineral characters, from any others in the field. They are mainly coarse ferruginous grits and conglomerates, with, in places, thin beds of loose white sandstone, and hard, brownish-red shales, micaceous in parts. Similar beds form Garangi Hill, and are seen,

Mineral character.

isolated by alluvium, at the village of Jamwa, and at Telinda or Madjia Hill, South-west of Rániganj.

With the exception of a few stems and imperfectly preserved leaves, no fossils have been met with in these beds, and, from their occurrence solely where isolated by alluvium, or upon hills, the sides of which are obscured by jungle and covered by blocks, which have fallen from above, it is impossible to ascertain, with any degree of certainty, whether this upper series is unconformable upon the Panchét group or not. The beds towards the top of Panchét Hill appear to dip at much lower angles than is the case at the base, and the same is seen, to a smaller extent, in Behárináth, and, apparently, in Garangi, but as all these hills abut against an enormous fault on their Southern side, no differences in amount of dip are sufficient to prove unconformity, unless the beds are seen in contact, which is not here the case. It is however probable that they are not conformable.

Mode of occurrence.

On Panchét Hill there are not above 500 feet of these beds, but Behárináth Hill,* which cannot be less than 900 feet, above the surface of the country at its base, seems to be almost entirely composed of them. As, however, the base is much concealed by fallen masses, their thickness may be considered as 500 feet.

Thickness.

* Behárináth is 1,480 feet high above the sea level, but not more than 900 above the plain at its base.

CHAPTER VI.—*On the relations of the Panchét to other groups of rocks in Bengal and Central India.*

THE subject of the relations of the rocks of Bengal and Central India having already been amply treated in these Memoirs, by Dr. Oldham,* in a paper written at the time when the Ráníganj field was undergoing re-examination, nothing remains, except to show what additional lights have been added by the various observations, whose results have been detailed in the preceding pages. The subject of the relations of the Ráníganj and of the Lower Damúda series has already been discussed, as far as is possible, until a more thorough examination of the fossils be made, than has yet been possible. The most important point, therefore, which remains, is the relations of the Panchét series.

The different groups as yet known associated with the coal bearing beds of Bengal and Central India are the following, in descending order :—

1. Mahadevas, with sub-group of Lameta beds.
2. Rájmaháls.
3. Upper Damúdas of Jabalpúr and Central India.
4. Lower Damúdas.
5. Talchirs.

The characteristic fossils, wherever any are known, being in all cases vegetable. The distinguishing forms of plants in the Lower Damúda, Upper Damúda, and Rájmahál groups, may be briefly expressed as *Vertebraria* and *Glossopteris* in the first, *Conifera* and *Lycopodiaceæ* and *Cycadeaceæ* in the second, *Cycadeaceæ* (*Palæozamia* and *Pterophyllum*) and *Tæniopteris* in the third; but there is a considerable generic, and some specific resemblance, between the Upper Damúda groups of the Nerbudda and the Rájmahál group, while there is none between either of those groups and the Lower Damúda—so far at least as now known.

* *Mem. Geological Survey in India*, Vol. II., page 299.—On the Geological relations and probable Geological age of the several systems of rocks in Central India and Bengal.

Even comprising the additional species procured from the Rájmahál series, there is no connection between the true Damúda group and the so-called Upper Damúda or Rájmahál group. The finding, therefore, of a species in the Panchét series, which is known to occur in the Ràniganj series, appears to show a closer connection with the Damúda group, and a smaller lapse of time than exists in the other instances.

The fossils of the Panchét group have not been compared with those of the Rájmahál and Upper Damúda series of Central India with sufficient detail and care to ascertain satisfactorily if any form be common or not. One *Sphenopteris* appears to occur, both in the Rájmahál and Panchét groups. There is, however, among the ferns, a considerable generic resemblance, greater than with the Damúda series. But the total absence of Zamias, which are so abundant and so strikingly characteristic in the flora of the Rájmahál series, appears, so far as negative evidence can be of value, to show that the Panchét rocks were formed either under very distinct climatal conditions, or at a different epoch of time from that of the Rájmahál group. The former is improbable, as the formations occur at a distance of little more than 50 miles from each other, and the natural conclusion must be that the Panchét group denotes a distinct epoch of time, and as there is one fossil at least common to them and the Damúda rocks, and none identical in the Damúda and Rájmahál group, that the Panchét series represents a period of time intermediate between that of the other two groups.

There is one test, judged by which the Panchéts would appear to approach much more nearly to the age of the Damúda rocks than to that of the Rájmahála, and that is, the relative amount of disturbance which they have undergone. The Rájmahál group has throughout hardly been disturbed at all, scarcely a single fault has been found in them. The Panchét and Damúda groups have been faulted and

disturbed, and afterwards trap dykes were introduced into them, which were very possibly of Rájmahál age.*

Such being the probable relations of the Panchét group to the other beds of Bengal, the question arises as to their connexion, if any, with the rocks of Central India.

To the "Upper Damúda group" of the Narbadda, Dr. Oldham† is inclined to assign an age nearly equivalent to that of the Rájmahále, but rather older. This would place them nearly on the same Geological horizon as has been above shown to be, in all probability, that of the Panchét beds. It is possible that the formations may be identical, but of this there is no indication in their floras, which are certainly fragmentary in both cases as yet.‡ And the absence of Cycadeæ and presence of Schizoneura tend much to induce the belief that the Panchét group is older than the "Upper Damúda."

The relations of the Mangáli shales of Mr. Hislop,§ with the Damúda rocks, are not quite certain, but they are probably higher in the general series. The remains contained in them show an interesting case of resemblance with those in the Panchét series. Of the plants obtained from Mangáli no description has appeared; but the animal remains comprise a reptile (*Brachiops laticeps,* Owen), fish, and Estheria. Of the latter, specimens have been presented by Mr. Hislop to the Geological Museum in Calcutta; and they appear to comprise two species, the smaller of which is undistinguishable from those found in the Panchét beds.

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* See below, Chapters VIII. and IX.

† *Memoirs,* Vol. II., page 324.

‡ The fossil evidence scarcely proves more than an approach to the same age, in the case of the Rájmahál and Upper Damúda groups. In the absence of any connexion between the last named beds and the Lower Damúdas, it appears by no means absolutely impossible that the "Upper Damúda" rocks might be even a little higher than the Rájmahál group.

§ *Quart. Journal,* Geo. Soc. Lon., Vol. XI., page 370.

The presence of this form, *Estheria*, taken in connexion with the occurrence of a Labyrinthodont reptile, gives an important clue to the age of the Mangáli beds, and gives interest to any thread of connexion, even if slight, between them and the rocks of Bengal.* But until the reptilian fossils of the Panchét group are examined, it is premature to enter into any further speculations.

The conglomerates and coarse ferruginous grits of Panchét and other hills might, from their mineral character and position in the series, belong to either of the groups described as "Máhádeva"† in Central India, or in Orissa‡; but any such identification could only be of the slightest kind on account of the distance at which these beds are known to occur, mineral character being a very uncertain guide in determining the relations of rocks separated by so wide an interval§ unless some very peculiar and marked character exists, as in the case of the Talchir rocks. But in the present instance there is no distinct character, beds of conglomerate and grit abound in rocks of all ages, while the extension of such beds over a large area is exceptional.||

* So far as this evidence goes, it tends to confirm Dr. Oldham's suggestions as to the Damúdas being Upper Palæozoic. For labyrinthodont reptiles, (and consequently the Panchéts if equivalent to the Mangális,) being Permian or Triassic, and the Damúdas being but little older, would be Upper Carboniferous or Permian, or perhaps intermediate between Permian and Triassic, but the evidence is very slight.

† *Memoirs*, Vol. II., page 183.

‡ Ibid, Vol. I., page 75.

§ The beds in the Damúda valley are about 250 miles from Talchir, those in Talchir are about 350 miles from Central India.

|| In deference to Dr. Oldham's opinion of the distinctness of the Máhádevas of Central India from those of Orissa (*Memoirs of Geological Survey of India*, Vol. II., page 315), I have treated them above as separate formations. The evidence of their identity was never very strong, and the Orissa beds were referred to the "Máhádeva" group as being the only known group then described to which they could be assigned. I do not think that any additional evidence with reference to them has since been procured. It will be seen above that I do not agree with Dr. Oldham's suggestion that the "Máhádevas" of Talchir and the upper grits of the Ránigaṇj field may be identical. It is by no means improbable that all three are distinct.

In all three cases, indeed, the evidence amounts only to this, that there are coarse sandstones and conglomerates of later date than Damúda age; that in Orissa and Central India the beds are of great thickness (2,000 to 3,000 feet), cover considerable areas, and rest unconformably upon the Damúda rocks. In the Damúda Valley there is no great thickness nor extent of the beds, and they rest, whether unconformably or not, is not clear, upon a formation unknown in the other two localities. As the Damúda rocks are certainly not of later date than Oolitic age,* the newer beds may belong to any subsequent epoch.

There is, however, a group of beds in the Rájmahál Hills, which presents greater facilities for identification. No description of it has been published, and it is therefore necessary briefly to allude to the general section of the formations there occurring, a sketch of which has already been given by Dr. Oldham,† in anticipation of the full description of them. The section is:—

1. Trap, with interstratified beds of shale and occasionally of sandstone.	Rájmahál group.
2. Coarse grits and conglomerates.	
3. Sandstone, shale and coal.	Damúda group.

The higher portion of the Rájmahál group, *viz.* the traps and inter-trappean shales, resting unconformably upon the grits and conglomerates, which again are unconformable upon the Damúdas. These grits and conglomerates appear to belong to the Rájmahál group, (they are certainly in no way connected with the Damúda series,) and form beds

(Subsequent research has shown the existence of vegetable remains, stems, &c., in the Panchét Hill rocks, which would appear to afford an additional reason for connecting these with the Máhádeva group of Cuttack. But the evidence at best is as yet exceedingly deficient.—T. OLDHAM.)

* Beds of the lowest Cretaceous group rest in Madras unconformably upon rocks of Rájmahál age, and the latter are far newer than the Damúdas.—*Mem. Geol. Survey of India,* Vol. II., page 323.

† *Mem. Geol. Survey of India,* Vol. II., page 313.

about 100 feet to 300 feet thick, stretching along the hills for 70 or 80 miles; their Southern extension, in the Rámghur Hills, not being above 50 miles distant from Rániganj.

There is nothing improbable in the conglomerates of Panchét, Behárináth, &c., being an extension of these beds. In mineral character they are similar. But it is possible that, being isolated and only slightly unfossiliferous, their affinities may never be satisfactorily determined.

So far as can be at present predicated, the following conveys briefly the probable relations of the beds of Rániganj, Orissa, Rájmahál, Central India, and Nagpúr.

I.	II.	III.	IV.	V.
Rániganj.	*Orissa.*	*Rájmahál Hills.* Rájmahál group.	*Narbadda Valley.*	*Nagpúr.*
1—*a*. Wanting. 2—*b*. Panchét conglomerates.	Wanting? ...	*a*. Intertrappean beds. *b*. Grits, &c.	Upper Damúdas.	Wanting.
3 Panchét group.				Mangáli shales. B.
4 Damúda series.				
a. Rániganj group.	*a*. Wanting?	*a*. Wanting.	*a*?	*a*?
b. Lower Damúdas.	*b*. Lower Damúdas.	*b*. Lower Damúdas.	*b*. Lower Damúdas.	*b*. Lower Damúdas. B. B.
5 Talchirs.	Talchirs.	Talchirs.	Talchirs.	Talchirs. C.

The letters in the last column being those employed by Mr. Hislop to distinguish the various beds in *Quart. Jour. Geological Soc.*, London, Vol. XI., page 370-371.

CHAPTER VII.—*Beds above the Panchét Group.*

I. *Beds of Khyrasol.*

Mineral character.

THE ridge of high land running from North to South, over which the Grand Trunk Road is carried West of Khyrasol, about 16 miles East of Ràniganj, and through which the Railway passes in a deep cutting near Kálipúr, is formed of coarse yellow and white felspathic grit, with beds of white, bluish-grey, and mottled clay, and thin bands of hard quartzose ferruginous grit. They are well exposed in the Railway cutting just mentioned, where they appear to dip about 2° to the North-east. There is no appearance of false-bedding. The grits are more earthy than those of the Panchét group, and abound in small angular pieces of felspar, which are much decomposed.

These beds occupy a considerable area, stretching from the Damúda near Khyrasol to the Adjai, but they are, in most part, covered and concealed by laterite. This area is at some distance to the East of the Ràniganj field, so that these beds are not represented upon the map which accompanies this Report.

Similar rocks in Beerbhoom.

Similar beds occur further to the North, beyond the More River, near Muhammad Bazar, and East of Deocha, on the Dwarka River, just South of the end of the Rájmahál Hills. Other sandstones, probably belonging to the same formation, have been noticed by Dr. Oldham and Mr. J. G. Medlicott, in Bánkúra and Midnapúr, and it is possible that the tract of sandstone lying South-west of the town of Cuttack may belong to the same formation.* If so, these beds, extending thus along the edge of the alluvium, deserve more notice than has hitherto been given to them. They are probably of very recent date, as their extension along the old coast line, and parallel to

In Bánkúra and Orissa.

* Not, however, the Máhádeva of Talchir, which are very distinct in composition.

the present one, seems to point to a geographical configuration of the land very similar to that now existing.

II. *Laterite.*

Concerning this rock but little need be said. It covers a considerable space to the East of the Ràniganj field, and patches of it occur within the area resting upon the Damúdas. It is uniformly gritty, and contains fragments of sandstone, evidently derived from the neighboring rocks. It attains no great thickness, being seldom seen to exceed 5 or 6 feet.

Laterite gravel.

Large areas to the East are covered with a gravel-like form of laterite, occasionally consolidated so as to resemble the massive variety. Whether this be precisely the same deposit, or whether it is merely the denuded and fragmentary detritus of the typical and massive forms of the rock, seems doubtful. There is much in favor of the former view. The gradual thinning which is observed, from the higher ground to the West, to the low plains of alluvium to the East, and the absence of any clear distinction between the two, or of any marked line where the massive form ceases, and the gravelly variety commences, in passing from East to West, seem to point to a common origin for both forms. The rise of level from East to West, already noticed as occurring in Orissa,* appears to be general along the East Coast, and further North, and perhaps an increase of it in the Rájmahál Hills, may explain the masses of laterite which cap their Western ridges. There can now be little doubt, but that the typical "detrital" form of the rock is a marine deposit, and that its peculiar mineral character is due to subsequent sub-ærial action, the iron having been originally deposited in the rock, and derived from the highly ferruginous metamorphic formations.

* *Mem. Geol. Survey of India*, Vol. I., page 274.

III. *Alluvium.*

Various kinds.

There are several forms which the various loose surface deposits of the Ganges delta and its neighborhood assume, each form probably corresponding to a distinct origin. Those covering and concealing the rocks of the Rániganj basin consist principally of three kinds.

1. Modern Alluvium, including the recent deposits from rivers, and the river alluvium of the Delta of Lower Bengal. These consist of sands and sandy clays, and cover but a small extent of country.

2. Old Delta Alluvium. This spreads over a considerable area, and the Damúdas and their associates disappear beneath it at the Eastern boundary of the known coal-bearing area. In some places it appears to contain gravelly laterite, in others it unquestionably overlies the laterite unconformably, and fills valleys, as that of the Singáran, from which the laterite has been denuded. In some places, as to the South-east of Ukra, and over a considerable area on the West flank of the ridge, extending North from near Khyrasol, the alluvium contains large deposits of mottled clays and coarse gravel, beds of quartz pebbles occurring in places.

But little is seen of either of the preceding formations within the Rániganj field; their history and relations are now being traced out over large areas, and by such means alone can they be fairly understood.

3. Old River Alluvium. The neighborhood of the Barákar and Damúda is covered in many places by considerable masses of gravel, with occasional sands and clays. They are well seen between the Núnia and Damúda, near their confluence, and along the North side of the Damúda, in the neighborhood of Hirapúr. They are frequently highly kunkuriferous, especially to the West, so that South of the Damúda, near Hirakúnd; near Hatinál, South of Chirkunda, and around Rámnagar,* (the last three

Calcareous bed with shells.

* Noticed by Mr. Williams as fresh-water limestone, with Unios.—*Report,* page 89.

places upon the banks of the Barákar,) massive beds of kunkur occur, and in the two last named localities, where the hardened calcareous rock forms a ridge along the bank of the river, fresh-water shells* and bones of oxen have been found.

In the same category may be placed the ferruginous conglomerate, which is found in many places plastered over the surface of the Damúda field, below other forms of alluvium. It frequently fills cracks in the sandstones. It consists of fragments of shale and sandstone, with rolled pebbles, strongly cemented together by oxide of iron. It is often exposed by streams. In one place, on the South bank of the Damúda, where it filled cracks in the sandstone of the Panchét series, fragments of bone of a very large mammal were found in it.

CHAPTER VIII.—*Trap Dykes and Intrusions.*

A GLANCE at the map, which accompanies this Report, will show the district to which it refers to be intersected in every direction by dykes of basaltic trap. Many of these are of considerable length, one at least, that which passes from a little West of Etiapora, through or near to the villages of Purani Chati, Dhadkia, and Dhámra, and South of the Damúda through Kálikapúr, which is known as the Sálma dyke,† extending for at least 20 miles, and being, doubtless, continued further, to the North. This dyke, where it crosses the Grand Trunk Road about a mile East of

Salma Dyke.

* *Unio marginalis, Paludina Bengalensis, Planorbis Coromandelicus, P. compressus,* and a small *Bythinia.*

† It was so termed by Mr. Homfray, from its passing close to a shaft, which he sunk in Sálma. The village itself is at some distance from the dyke, and lies a little South of the Damúda.

Asansol dâk bungalow, is about 120 feet broad, and it has throughout a general direction of South 20°—25° East. No other dyke, within the area of the field, attains equal dimensions, although a few nearly parallel with it, are of considerable breadth (30 or 40 feet), and can be traced for many miles. By very far the largest portion, however, do not exceed 3 feet across, but even these may, in many instances, be seen to extend for 5 or 6 miles.

Mineral character of dykes.

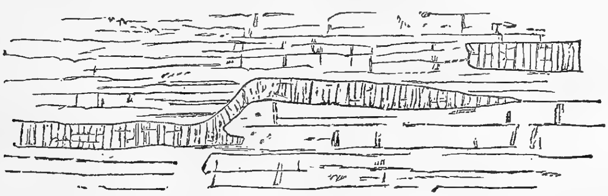
The trap forming the various dykes differs greatly in mineral character. It is generally more or less decomposed, and frequently contains a whitish micaceous mineral, somewhat resembling Margarodite, in little rounded masses. In many instances it contains black mica. But these distinctions do not certainly prove difference of age, for two or three varieties are frequently found in the same dyke, in different portions of its course. Small pieces of gneiss and granite, brought up evidently from the metamorphic rocks, which must be in some places 10,000 or 12,000 feet below the surface, abound in some of the dykes, and occasionally in very small ones.

Distinction as to age.

Among the great mass of the dykes in the beds of the Ráníganj field, above the Lower Damúdas, no reliable distinction can be made as regards age. There are, however, some appearances, which induce the belief that the traps running in general East and West, between Etiapora, Sámdi, and the Barákar, those North of Chúralia and Madanpúr, and others in the Lower Damúdas, are older than those spread over the remainder of the field. Their distinctive peculiarities will be described presently. There seems, among the greater number of the remaining dykes, to be a prevalent direction, averaging North-east and South-west, a far larger number striking between North and East than between North and West. This is doubtless due to the circumstance of the forces which had disturbed the district previous to the trap intrusions, having produced numerous cracks in this direction, which is that of a large

number of the principal faults, those faults having been in all cases where intersection has been observed of older age than the trap. Many apparent cases of trap dykes being faulted arise simply from the crack which they have filled having split somewhat irregularly in that place, as in the accompanying diagram, Fig. 9. There is a case close to the village of Amkula, West of Rániganj, where a dyke is thrown 120 feet in this manner without any fault.

FIG. 9. DYKE THROWN WITHOUT A FAULT NEAR BONGHA.



It is also possible that the Salma dyke, and a few other large dykes, lying West of it, and parallel with it, and which are composed of a very compact trap, often finely columnar, may be of a different age from the smaller dykes; but there is no proof of such being the case. Relatively to each other, there can be no question that some dykes preceded others. There are very many cases where a newer dyke is seen to cut an older one. This may be observed in numerous instances in the country immediately West of Rániganj, and nowhere better than in the two parallel dykes which pass through the colliery, and separate the old abandoned mine from the new one now worked. One of these is seen to cut across the other four or five times at least, and affords an interesting example of a second dyke following approximately the same general line of weakness which a former one had taken. But there is no evidence that this difference of relative age implies a difference of Geological Epochs. Just as in any volcano, where a section is exposed, some dykes may be seen cutting others, and yet all may have been formed within very few years of each other, and the whole mass

within a portion of a Geological Epoch, so, in this case, the mere fact of some dykes having slightly preceded the others, by no means proves them to have had a distinct origin. The most careful examination was devoted to an endeavor to trace out a supposed case of a distinct series of dykes, but the conclusion was that, with the exception of those already referred to in the Lower Damúdas, all were of the same general age.

Geological age of dykes.

As regards the Geological age, there appears good reason for supposing that these intrusions may have been contemporaneous with the great volcanic outbursts, of which evidence exists in the Rájmahál Hills. The dykes are certainly newer than the Panchét rocks, which they traverse in abundance, and they are also newer than all the faults of the districts. Now, however much evidence there may be of faulting and disturbance preceding the Rájmahál period, the rocks belonging to that formation have, in the district where alone they occur in Bengal, scarcely been moved from their original horizontal position; and faults are very rare amongst them. It is probable that a period of elevation and of great and long continued disturbance was concluded in Bengal by the outbursts of lava now forming the range of hills which stretches from the neighborhood of Soory to the banks of the Ganges.

No evidence of later volcanic action is known to exist in any part of Bengal. The circumstance of scarcely any disturbance having taken place at a more recent period is, in itself, strongly in favor of the belief that the trap dykes of the Damúda country are not newer than the lava flows of the Rájmahál Hills; for had volcanic action taken place, it would probably have been either preceded or accompanied by disturbance. If, therefore, it be conceded, that the age of the trap dykes is not newer than that of the Rájmahál rocks, the period during which they might have been formed is reduced to a comparatively small range.

There is no reason for supposing that the trap outbursts of Central India and the Deccan ever extended to the neighborhood of Bengal, unless they were contemporaneous with the traps of the Rájmahál Hills, a view opposed to the opinions entertained by all Indian geologists; the Deccan traps being considered Eocene. It is, therefore, highly improbable that the dykes of the Ràniganj field should be in any way connected with them. And the balance of probabilities appears to be in favor of those dykes being of Rájmahál age.

Faults accompanying dykes.

It is remarkable, considering that both dykes and faults must necessarily take place along lines of weakness—along cracks in the rock, in fact—that instances of their accompanying each other should be so singularly rare in the Damúda Valley. Only two cases were observed. Of these one is the dyke (No. 6 of Mr. Williams*) which runs nearly due North and South along the valley West of Sirsol, and passes just West of the out-crop of the Sirsol coal seam; the other is on the North boundary of the field, just East of the Barákar. A fault runs North-west from near Debipúr to the temple at Debitán. The Southern portion of this is accompanied by a trap dyke, which, however, is clearly more recent than the fault, for the latter is cut off close to Debipúr by a second fault, running about East 20° North, while the dyke is continued for some distance without being thrown. Doubtless other cases may exist of faults and dykes being along the same lines, but had they been other than extremely scarce and exceptional, more instances would certainly have been noticed. It is evident that the disturbing forces producing pressure on the beds, and tending to crack them, at the time when the traps were intruded, were distinct from those existing in the previous period of dislocation and disturbance.

* The dykes marked on Mr. Williams's map were all numbered, but, as before stated, they were a very small portion of those which existed.

In many instances, the traps, instead of forming vertical dykes, have intruded themselves between the planes of stratification, or have traversed an easily yielding bed, such as coal. This is especially the case in the Lower Damúdas, and is, indeed, almost distinctive of the traps there occurring. It is best seen in the area already referred to, extending for a considerable distance in an Eastern and Western direction, near the North boundary of the field, and parallel to it, and which was mapped by Mr. Williams as a ridge of intrusive trap, extending from Etiapora to beyond Samdi. The trap becomes noticeable, in fact, near Chúralia, North of which village two runs of interstratified traps occur. A little further West, North of Madanpúr, Kapista, &c., a long ridge of low hills occurs, which forms, for some distance, the Northern boundary of the field. This consists of two or three runs of trap, and of the sandstone hardened by it. The great North-west and South-east fault, which runs between Alipúr and Etiapora, and has a down-throw to the North-east, throws the outcrop of these traps and sandstones for some miles to the South. They are seen at Etiapora, and abound from thence in the ridge of ground on which stand the villages of Bila, Amdia, Mohanpúr, Pahargora, Samdi, &c.; the little hill of Muktochandi is a mass of intrusive trap. Again to the West of the West branch of Núnia these traps stretch across through Dandarbád and Sabúnpúr. They are less conspicuous near the Barákar and West of it.

Trap intruded horizontally.

These dykes alter and harden the sandstones with which they come in contact to a great extent, more than their size, for they are seldom of any thickness, would lead any one to anticipate. But their principal effect is upon the coal beds. In describing the enormous deposits of fossil fuel which occur in the Lower Damúdas, the great injury done by the traps occurring associated with them was repeatedly referred to. Seam after seam is found traversed by these dykes, which permeate the coal in the

Effect on the rocks.

most irregular manner, altering and hardening it, and at times causing it to assume a perfectly columnar structure. Apparently the coal has been fused by the trap, and the latter has been driven into the seam, wherever it could force itself a passage.

Not contemporaneous.

The almost universal parallelism of these dykes, with the beds among which they occur, almost of necessity induces the belief, at first sight, that they are interstratified lava flows of contemporaneous age, like those of the Rájmahál Hills or of the Deccan. More close examination, however, shows that the rocks, both above and below, are altered by them, and that if traced for any distance, they, in general, cut across the strata. But, in coal seams, there can be no question, from their irregularly intrusive character, that they are of posterior and not contemporaneous formation. And in sandstones, they are occasionally seen to split up and anastomose, in a manner which can only be due to intrusion.

Principally in Lower Damúda group.

These dykes (for they are dykes, although horizontal and not vertical) are, as already remarked, almost confined to the Lower Damúdas. A few instances, however, occur in the Ràniganj series. One of these is seen stretching from the central branch of the Núnia, South of Madanmonpúr, to near Sripúr; another occurs about 1½ miles further East, near Kaithi, and a few instances of coal, intersected by trap, have also been referred to; that near Chalwidi, on the Núnia, West of Ràniganj, and of the seam just below that worked at Maïnanagar being examples. But these are singularly rare, when compared with the great prevalence of such horizontal trap intrusions among the sandstones, and far more conspicuously among the coals, of the Lower Damúdas. So numerous were these little irregular dykes in that group of beds that it was found impracticable to map any, except the most important and conspicuous.

It is worthy of remark that the neighborhood of Samdi and of the

little trap hill of Muktochandi appear to abound more in trap than more distant localities. Also the great prevalence of the traps in one particular bed of sandstone is noteworthy, but it is probably due to the circumstance of that bed being more easily permeable than others, and of all the dykes being merely branches and ramifications of one great dyke. The principal reasons for supposing these dykes to be of a different age from those which occur in the higher beds of the field, are, 1*st*, the very much larger amount of trap permeating the Lower Damúda beds;* and, 2*nd*, the circumstance that these horizontal dykes, and these alone, appear to be thrown by faults, especially by that near Etiapora. They are also thrown by two small faults North of Chúralia, and by another North of Madanpúr. This may, possibly, be due simply to the permeable bed being thrown, and to the trap of subsequent age, selecting that bed, although dislocated, wherever it occurs, much as coal at all heights in the Lower Damúdas appears to be penetrated in preference to any other rock; but this is less probable than the theory of the horizontal traps being of prior age to the faults, and perhaps of older date than the ironstone shales and Ránigan series, the very few instances of horizontal dykes in the latter being easily explicable by supposing that the planes of stratification proved, in a few instances, to be the principal lines of weakness. It is easy to conceive that in a country already disturbed many more cracks would occur through which trap could be forced than in a district where the rocks had not undergone dislocation, and that, in the latter instance, the weakest lines might be the planes of stratification, and the more easily yielding beds of the series, so that, judged by this test, there is a probability of horizontal dykes preceding the upheaval of the country, while vertical dykes are of latter origin.

Two series of Dykes.

Taken altogether, the whole circumstances show it to be probable that

* This might be due, however, to their being lower and nearer the sources of the trap outburst.

there are two series of dykes in the Rániganj field, the older one of which is of Damúda, possibly of Lower Damúda age, and the newer of the same period as the Rájmahál group.

The older or Damúda dykes are almost invariably decomposed and soft, forming a red or yellow stone; they consist of fine grained trap, frequently vesicular.

Local outbursts of trap.

Besides regular dykes, there are a few local outbursts of trap. This is the case with several small hills North and North-east of Afzalpúr; they, however, being confined to the gneiss, may be of older date. One, known as Maluncha Hill, near Nala, in Kúndit Kuráya, is the largest. Within the area of the field, the most noticeable is Muktochandi Hill, which, however, is of no great size. Two small masses occur, one beneath the barracks at Ránigani, and another a little to the West of them, while a third is seen about half a mile South-west of Parassia village. The last-named is amygdaloidal, and contains agate. These outbursts are, doubtless, of the same age as the dykes, from which they merely differ in greater breadth. That at Muktochandi Hill, near Samdi, and a smaller one in the village of Pahargora, may, perhaps, be of the same age as the neighboring horizontal dykes, which appear to have some connexion with them, but it is equally probable that they belong to the newer series.

CHAPTER IX.—*Faults.*

MUCH of the most important information which has been accumulated concerning faults has already been stated in the preceding section. Very much remains to be ascertained upon this subject which can only be thoroughly understood, when far greater facilities exist for examining the various strata than is now the case. This is

unfortunate, for no question can be of greater importance to the miner than to know, by the help of a geological map, where he may expect to meet with faults or "troubles," and if he intends to mine beyond them, in which direction is the down-throw.

Even some of the largest and most important faults in the field cannot be traced for any great distance into the sedimentary rocks. The difficulty of following them has induced a strong belief that they are more numerous, and the throw greater, in the Lower Damúdas and Talchirs, than in the Ráníganj beds and Panchéts. This seems especially the case with the numerous faults running about North 20° East in the neighborhood of Jamiari, none of which can be traced to have any effect upon the ironstone shales, the boundary of which, however, is by no means clearly seen in the places where it should be intersected by the faults.

Three principal series.

The greater number of the dislocations occurring in the Ráníganj area may be divided into three series of parallel, or nearly parallel, faults.

I. A series running about West 10°—20° North: to this belongs the great fault forming the Southern boundary of the field. One other fault may also be referred to it, *viz.* that forming the Northern boundary of the field from the Adjai, near Daskiara, North of Etiapora, to beyond Birkunti. It is extremely probable that this series of faults may not be entirely the effect of one period of disturbance, but the accumulated dislocations of many movements at various times. It belongs to a series which has enormously influenced the rocks of Bengal and Eastern India, and the throws are frequently, as in the present instance, of gigantic dimensions.

Enormous fault on South boundary.

There is perhaps no example on record in which the throw of a large fault had been determined with greater accuracy than in the case of that bounding the Ráníganj field to the South. The steady dip of beds, whose out-crop extends in

places over 20 miles of country, is, in portions of the field, perfectly uninterrupted. The thickness of the various formations, excluding the Upper Panchét and Talchir rocks, has been shown to be about 10,000, and as there is no amount of unconformity between any series above the Talchir, which can possibly account for an absence of more than 1,000 feet of rocks altogether, and as all the beds are cut off by the South fault, all the higher ones abutting against it, it is only reasonable to conclude that the throw of the South fault *cannot be less than* 9,000 feet, or nearly 1 mile and three-quarters. How much more it may be it is impossible to say. It is probably more than 12,000, for the above are minimum measurements, and the throw is only known to exceed them.

Comparison with Talchir field.

The great fault which bounds the North of the Talchir field is parallel to that on the South of the Rániganj field, and, although at a distance of 250 miles, may very possibly be due to the same disturbing forces. Its throw, however, is reversed. Indeed, the two fields of the Damúda and Bráhmani Rivers have some singular points of resemblance, both being brought in by parallel faults, which cut off the whole of the rocks comprised in them. This, indeed, appears to be the prevailing character of the small areas of Damúda, Talchir, and other sedimentary rocks dispersed over Bengal and Orissa, and the districts lying immediately West of them.

Another parallel fault, of great size, exists in the gneiss of Kúndit Kuráya. It is marked by scattered rises, composed of the breccia, which, in the metamorphic rocks, and occasionally, in the Talchir, but never, so far as is known in Bengal, in the Damúda rocks,* accompanies most faults of any size. The great faults of Central India appear to follow a different direction from those in Bengal, but, in the latter province, it is probable that nearly all the largest faults have an Easterly and Westerly direction.†

* It occurs, however, between Damúdas and Metamorphic rocks, and contains fragments of both.

† Or more correctly East by South to West by North.

Second system older than others.

II. The second system of faults strikes North 10°—20° East, and is perhaps older than either of the others, or, even more probably, may be newer than the commencement of the East and West series, but older than its completion. To this system belong the faults forming the West boundary of the field from Rámpúr, near the South boundary, to near Chánch and Núchibád; the fault down the valley of the Barákar, (which is possibly the same as that West of Panchét, but thrown by the North-west and South-east faults bounding the field West of Chánch;) several small faults near Jamiari, and North of Samdi, on the North boundary of the field; and perhaps the small faults which throw the boundary of the Panchéts East of Asansol, and those which occur West of Rániganj colliery.

The fault down the Barákar is clearly proved by the throw of the boundaries of the ironstone shales and of the lower beds. No trace of it, however, can be seen upon the river banks, and it probably follows throughout the course of the stream, curving slightly below Rámnagar.

Third system.

III. Faults running North-west and South-east, or nearly so. These comprise the faults forming the West boundary of the field from near Chánch to the extreme West near Kalatabúr; a small fault at Debitan, just East of the Barákar; that near Alipúr and Etiapora; that North of Madanpúr; and the fault in the Adjai. All of these, except the Debitán fault, which may not belong to this system, but be an older fault of Talchir age, have the same down-throw, *viz.* to the North-east. They are evidently newer than the North 20° East faults, which they cut off in the West of the field and probably throw.

The faults forming the South-west boundary of the Panchéts, South of the Damúda, may, perhaps, belong to this system. The attempted tracing of the faults from Chánch across the country North of Marúlia, is not quite certain. It is however probable that a large fault does

exist there with a down-throw to the North, for the run of ironstones mapped in the Rániganj series comes in immediately North of the anticlinal, which traverses the country in the same direction as the fault, while many hundreds of feet of rocks intervene to the South of it, and the presence of some displacement is indicated by the peculiar twists and singular dips seen North-east of Marúlia. (*See* p. 120.)

There are a few other faults, which cannot, with certainty, be referred to any of these three series. Such are the small throws influencing the South-west boundary just North of where it crosses the Grand Trunk Road near Báreghar and Barwa. These are, however, of small amount.

Some of the most important faults accompany twists in the strike of the rocks. One of these changes of strike occurs about the valley of the main branch of Núnia, where it runs from North to South, from Etiapora to the neighborhood of Asansol. Another occurs near the Barákar, the dip of the rocks changing from S. S. E. to S. S. W. in each case. It is probable that both phenomena were due to the same disturbing causes.

Age of faults.

The age of the faults, as a mass, has already been shown to have been probably in the time which intervened between the Panchét and Rájmahál periods. No additional evidence of importance exists beyond that afforded by the dykes. All three series throw every rock from the Panchéts downwards—their effect upon the Panchét grits is unknown; but there is no doubt that they were thrown by the East and West fault forming the South boundary of the field, as no outliers of them are known to exist beyond.

There appear to have been faults in the Talchir rocks previously to the formation of the Damúdas, but their direction has not been clearly made out.

Part II.—COAL MINES.

Chapter I.—*History*.

An account of the earliest attempt at working coal in the Rániganj field will be found in a paper published by Mr. S. G. T. Heatly, in the *Journal of the Asiatic Society of Bengal* in 1842,* and which shows by a series of extracts from the records of public offices, the principal details of the opening of the first mines. In August 1774, Messrs. S. G. Heatly and J. Sumner, of the Bengal Civil Service, made an application to Government for the right of working mines of coal, the discovery of which they announced, in "Pachete and Bheerbhoom." Mr. S. G. Heatly was at the time Collector of Chota Nágpúr and Palamow, and he was, in all probability, the first discoverer of the existence of coal in Bengal. A Mr. Redferne subsequently joined the firm, which, as Sumner, Heatly, and Redferne, applied for an exclusive right for eighteen years, (which was granted,) to work and sell coal in Bengal and its dependencies. The limits of the area, within

* (Contributions to a History of the Mineral Resources of India, No. I.,) Vol. XI., page 811.
The following account is based on information derived from this paper, from Mr. Homfray's papers and from some letters of Mr. C. B. Taylor to the *Englishman* and republished in 1849, (the latter only quoted for dates,) and from general information obtained from owners and managers of mines.

which they applied for and obtained permission to mine, were the Adjai and Damúda Rivers, on the North and South, a semi-circular line drawn from the village of Aitúra, with a radius of 10 miles to the West, (this carried their boundaries for some distance beyond the Barákar,) and the border of Burdwan on the East.* They agreed to pay one-fifth of the produce to Government, and to supply for five years 10,000 maunds per annum, at a price of 2 Rupees 12 annnas per maund, probably the value of English Coal at the time.†

In 1775 Messrs. Sumner and Co. announced to Government the arrival of 2,500 maunds of "Pachete coal," and requested that it might be received. Such does not, however, appear to have been done until 1777, when fresh application having been made, the Government directed the Commissary of Stores to report upon the coal. From experiments he concluded that it was only half as good as English coal, and it was consequently returned to the firm, with an intimation from Government, that they would still give every assistance to the miners in endeavoring to procure coal of better quality, for which they recommended further search and deeper excavation.

1777.

Position of first mines.

The mines first worked by Messrs. Sumner, Heatly, and Redferne, and, subsequently, by Mr. Heatly alone, are said to have been six in number, three of which were at Aitúra (Aytooreah), Chinakúri, and Damúlia. It is difficult to ascertain which were the others; some were probably in the neighborhood of the Barákar, the portion of the field East and West of Ráníganj, not being, probably, then known to contain coal. The mine (quarry) at Damúlia was, doubtless, close to that now worked, and that at Chinakúri was probably near the village of that name, upon a lower seam

* This must have been at that time further East than it is now. One of their mines, Damúlia, is in Burdwan.

† The present price of Ráníganj coal is, and has been for many years, from 6½ to 7½ annas in Calcutta.

than that now mined. The position of the Aitúra mine is more doubtful, as no coal is known in the neighborhood of the village ;* it was probably on the seam now worked by Messrs. Apcar and Co., at Sitarámpúr, along the out-crop of which, on both sides of the Núnia, old workings of considerable extent exist.

It is stated that Mr. Heatly procured English miners, and made preparations for working the coal upon a large scale. Fever, however, carried off the men. Mr. Heatly himself was removed to a different part of the country, and it is doubtful if any of the coal mined was brought into the market.

1808.

Nothing further was done for thirty years. In 1808, the Government of India, in consequence of the difficulty they experienced in procuring coal in sufficient quantities from England, made some enquiries concerning the coal on the Damúda, but apparently without any practical result for the time. In 1814, however, just forty years after Mr. Heatly's quarries were commenced, a Mr. Jones was sent by the Government to examine the district in which they had been situated, and the result of his mission was the re-discovery of Mr. Heatly's workings. Mr. Jones also found the seam at Ránigañj, and began to work it upon his own account, about 1815;† a sum of 40,000 Rupees being advanced to him from the public treasury, at a low rate of interest, to enable him to do so. He mined and sold coal, and that from pits, not quarries, and probably was the first who ever brought Indian coal into the general market; but either he did not succeed in extracting it profitably, or, as is more probable, he failed in other speculations, for he was unable to repay the Government loan; and an Agency

1814—Mr. Jones.

Ránigañj opened 1815—1817.

* I made enquiries on the spot, but could learn nothing as to the position of Mr. Heatly's mines.

† Or perhaps a year or two later.

house, Messrs. Alexander and Co., who had been security for Mr. Jones, were obliged to do so. The pottahs of the land on which the mine was were, doubtless, placed in their hands, for they became the owners of the colliery about 1820.

Frequent disputes.

The history of the Rániganj field from that period is the history of one continued succession of fightings and litigations. The constant endeavors of Messrs. Alexander and Co., and of their successors, was, not unnaturally, to obtain a monopoly of the valuable coal district around them, and to prevent any one else from establishing himself in it. For every mine it was necessary to have, not merely a lease or pottah of the land on which the coal was procured, but also of a ghât or shipping place from which the coal could be sent by the river to Calcutta, and permission to make a road to connect the two. Labor was also necessary, and, for the purpose of obtaining command of it, it was, and still is, customary to procure from the proprieters leases of villages. On all these points, amongst a race of litigants, and with the peculiar facilities afforded by the laws and customs of the country for the promotion of legal disputes, it would be strange if questions as to right of ownership, right of way, and rights of every sort and kind, should not constantly be arising: and they did arise most abundantly. When endless law suits were the price at which alone it was possible for any one to commence mines in the Rániganj district, it is not surprising that the greater number of speculators would be discouraged, and that the longest purse would, in the end, have all the advantage. But even if the real facts could be ascertained, no information of value would be gained from a detail of the petty squabbles of the various coal owners, although, on the whole, they have had a most important effect in impeding the progress of the district. Divested of unimportant circumstances, the following is a brief summary of the order in which various mines were commenced.

In 1823, or the commencement of 1824, Chinakúri Colliery was opened by Mr. Betts, probably upon the spot where had formerly been Mr. Heatly's works. Damúlia was, about the same time, or a few months later, in 1824, re-opened by Messrs. Jessop and Co., but they lost it sometime afterwards by a law suit, and opened Narrainkúri in 1830. The Salúnchi seam (near Chinakúri) was first worked a year or two after, and the old mine at Chinakúri was abandoned at the same time, or soon after about 1836.

Chinakúri, 1823-24.

Damúlia, 1824.

Narrainkúri, 1830.

Salúnchi, 1831-32.

The quarries at Chánch and Núchibad were also commenced about 1830, or within a few years subsequently, by Mr. Homfray, of the firm of Jessop and Co. Chokidánga, Mamadpúr, was opened by Dr. Rogers in 1834, and Dhosúl by Mr. Blake about the same time.

Chánch and Núchibad, 1830.

Chokidánga, Dhosul, 1834.

Within a few years from this time several of the principal collieries then existing passed into the hands of other proprietors. One thousand eight hundred and thirty-five was a bad commercial year, and many large agency houses failed, among them Messrs. Alexander and Co. Ràniganj mine was purchased by Bábú Dwarkanath Tagore, and subsequently worked by the firm of Carr, Tagore and Co. It is said that, so much was the value of such property depreciated at the time of the sale, that the whole estate, including several valuable *patni* and other tenures, together with all the buildings, and works, steam engines, &c., on the mine, nearly 250,000 maunds of coal* at market, and a large quantity more at the mine, together with all advances made to boatmen, was sold for 70,000 Rupees: less than the value of the coal at market alone!

Carr, Tagore and Co., 1855.

In 1837 Narrainkúri, Chánch, and Núchibad passed into the hands

* Above 9,000 tons.

of Messrs. Gilmore, Homfray and Co., and in the same year Chinakúri was purchased from Mr. Betts, Junior, by Messrs. Carr, Tagore and Co.

Gilmore, Homfray and Co., 1837.

Mangalpúr, 1840.

Mangalpúr and Rogonáthchuk were opened in 1840 by Mr. Erskine. About this time, or a little earlier, quarries were worked by Messrs. Carr, Tagore and Co., at Deziragarh, Hirakúnd, and Narrainpúr (or Núdia), while others were carried on by natives at Barmúri, Beldanga near Rániganj, Kantagoria (now Bhángaband), and some other places.

Bengal Coal Company, 1843.

In 1843 the concerns of Messrs. Carr, Tagore and Co. and Messrs. Gilmore, Homfray and Co. were amalgamated into the Bengal Coal Company, who abandoned Narrainkúri, and for the time, almost all their mines, except Chinakúri and Rániganj, the old mine at the latter place having been destroyed by fire in 1842. A new mine, however, was at work before the loss of the old one. This Company has existed ever since, and has now, by far, the most extensive collieries of any proprietors in the field.

1840-47—great increase of workings.

From 1840 to 1847, (during which period Mr. Williams's survey took place (1845-46); the two papers by Mr. Homfray, already mentioned, were published (1842 and 1847); and the final report of the Coal Committee was issued (1845),) there was a constant and large increase in the quantity of coal mined. According to Mr. Homfray, the number of maunds imported into Calcutta from Rániganj was, in 1839, 10,00,000—in 1846, 25,00,000. The Coal Committee give 17,00,000 as the probable consumption in 1845,* and 12,00,000 for the average of the four previous years. Mr. Homfray's figures give respectively 20,50,000 and 16,30,000. Several new mines were opened; among them Sirsol, by Bábú Gobind Parsád Pundit; Nimcha,† Sangamahál, Gopináthpúr,

* Report of 1845, page 150.

† In a different spot from the present mine. These mines were scarcely worked at all.

and Kásta, by Messrs. Grob, Dürrschmidt and Co.; Sitarámpúr, by Messrs. Apcar and Co.; Kumardhubi and some other mines, by the Indian Coal, Coke, and Mining Company.

Continued progress since 1847.

There has been, on the whole, a steady progress since that time, both in the number of collieries worked, and in the total quantity of coal produced. The latter, especially, has increased to a great extent since the railway has afforded increased facilities for transmission to a market. This has produced an important change in two ways: *First*, by greatly stimulating mines in its own immediate vicinity, that is, in the neighborhood of Rániganj; and, *secondly*, by rendering possession of the ghâts unnecessary while the roads are easier of access than the river. Its own requirements also have very materially increased the demand for fuel.

Railroad opened.

New mines.

The list at the close of this Report shows the existence in 1860 of no less than forty-two collieries,* and a production, on the average of three years, of 78,08,566 maunds or 281,994 tons of coal, coupled with a considerable increase in the quantity mined in the course of that period. The amount is now treble what it was in 1846; several most promising mines, as Harispúr, Babúsol, Tapassi, Parassia, and Nimcha have either commenced or been resumed, and the value of mining property has greatly risen. And there appears every reason to anticipate a continued increase in the production of this rich mineral district. The greatly increased demand which the extension of the railways in the Ganges Valley and in Lower Bengal must produce, and the aid to distant collieries which the additional lines within the field will give, must produce a corresponding augmentation of the supply. The quantity of coal is practically unlimited, and if the difficulty of supply of labor can be overcome, there is no

* Seven mines or quarries worked in 1858 or 1859 were closed in 1860. In some of these the closing is merely temporary, pending the erection of machinery.

reason why Ráníganj may not be, half a century hence, one of the richest and most important districts of Bengal; especially if the manufacture of iron be successfully introduced.

Chapter II.—*Present condition of the Coal Mines and methods of working employed.*

Within the known coal-producing area of about 500 square miles, there are now at work nearly fifty collieries, distributed between about fourteen proprietors or proprietary Companies, European or Native. These collieries vary in size, from large concerns, with numerous pits, several steam engines, and an out-turn of 18 or 20 lakhs of maunds (60,000 or 70,000 tons) of coal annually, to small quarries, a few feet square, where half a dozen coolies extract, perhaps, 20,000 maunds of inferior coal in the course of the year.

Collieries, number of.

The collieries may be divided into those worked by pits, and those where the extraction is confined to quarries on the out-crop of a seam of coal. The latter has been the first stage of almost every mine in the field, pits not having been resorted to, until the workings became so deep, that it was inconvenient any longer to extract the coal from quarries, or until the water could no longer be kept under by the primitive methods adopted. In most of the smaller collieries, whether worked by pits or by quarries, the water is raised by the same contrivances as are commonly employed in Bengal for irrigation and for wells. Of these contrivances, the principal is the common "térah,"* a long horizontal pole or bamboo, working on the top

Two kinds.

Open quarries.

* The "paicottah" of Madras.

of two vertical poles, and having a bucket, or an earthen pot, attached to its longer end by a vertical bamboo, while its shorter end, bearing a stone or a mass of mud as a counterpoise, is hauled down by ropes. Another plan, less used, is to haul up a skin bucket over a pulley. Mat scoops, worked by two men, are occasionally used, especially in steep under-ground galleries, if the lift does not exceed 2 or 3 feet, such small lifts being repeated at frequent intervals, and the water being, in most cases, ultimately raised to the surface by the "térah."

Pits.

Pits from the comparatively small depth and from the low cost of labor, are very inexpensive, and, consequently, many more are sunk than is the case in England. They are almost invariably circular, and are usually sunk in pairs, in which case they are 8 to 10 feet in diameter. "Double pits," in which two buckets are used, are 12 feet across. The rocks overlying the coal, throughout the Ránigan series, are mostly sandstones of various kinds, sufficiently firm to support the shaft, so that bricking is only necessary close to the surface. The majority of the pits now being worked do not exceed 100 feet in depth, and no pit has yet been sunk exceeding 230; the new engine shaft at Chinakúri, which is of that depth, being the only pit at work above 200, although one or two are now being sunk. These are extremely shallow when compared with any English collieries, and insignificant by the side of the deep pits, some exceeding 2,000 feet, in the North of England.

Thickness of coal seams.

The coal seams mined vary much in thickness; that of each will be seen by reference to the table at the conclusion of this Chapter. The thickest seam worked is at Kásta, North of the Adjai River, where the bed, with its partings, is, in one quarry, 35 feet from top to bottom. The whole of this is removed in the quarry. No very thick seam can be worked out by the system at present employed for under-ground working, the sole plan used throughout the field, irrespectively of the

thickness of the seam mined, being one of the numerous modifications of the system, known in England as "post and stall," or "pillar and board." The coal is extracted in galleries, crossing each other at right angles, square "posts" or "pillars" of coal being left to support the roof. The size of the pillars and galleries varies in different collieries, depending upon the firmness of the roof, or stratum overlying the coal, and, to some extent, upon the thickness of the coal itself. Where the roof is good, and the coal seam of moderate thickness, the size of the pillars is smaller, and *vice versâ*. Of course the smaller the "pillars," and the broader the galleries between, the greater will be the quantity of coal extracted from any given area; since, although as much coal as possible is robbed or cut away from the pillars, before abandoning the mine, only a small proportion of the mass can be thus extracted, the major part of what is left at first being inevitably lost, and a further advantage in widening the galleries or "boards," is the additional space given to the workmen to use their tools freely.

"Post and stall" workings.

Sizes of pillars.

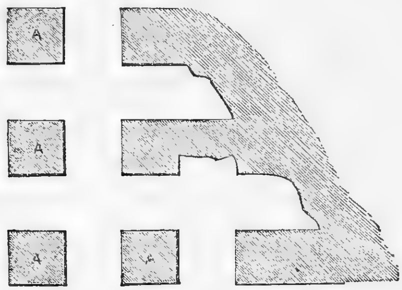
The following are the sizes of the galleries and pillars in a few of the principal mines around Ràniganj :—

In Ràniganj mine,	the pillars are	15	feet square,	the galleries	15	feet broad.
In Sirsol mine,	ditto	15	ditto	ditto	12	ditto.
In Tapassi mine,	ditto	12	ditto	ditto	12	ditto.
In Chokidànga mine,	ditto	15	ditto	ditto	14	ditto.
In Harispúr mine,	ditto	18	ditto	ditto	14	ditto.
In Rogonàthchuk mine,	ditto	18	ditto	ditto	12	ditto.

It will be easily seen, that where the "pillars" and "boards" or galleries are equal in breadth, three-quarters of the coal is removed in the first instance. This is the most favorable case, and exists in Ràniganj and Tapassi collieries. Allowing, on the one hand, for the quantity of coal which it may be found practicable to "rob" from the

pillars before abandoning the mine, and, on the other, for the quantity of small coal and shale extracted, it is evident that, under the

FIG. 10. DIAGRAM SHOWING MODE OF WORKING AT RANIGANJ COLLIERY.



Method of working coal in the Ráníganj field, the shaded parts represent the coal, the unshaded the galleries from which it has been extracted; A A are the posts left to support the roof.

most favorable circumstances, not more than two-thirds of the coal can ever be obtained in a marketable state, and in most collieries the proportion is unquestionably much lower—probably not more than half.

In Ráníganj mine the seam, as before described, has a thickness of 13 feet 2 inches, the section being—

	Ft.	in.
Hard black shale.		
Coal	9	0
Shale parting	0	3
Coal	0	9
Shale parting	0	2
Coal	3	0
Under-bed of shale.		

Of this, the upper 9 feet bed is first removed by the method described, and afterwards, the two thinner beds are extracted from the floor of the galleries. The roof, which consists of shale, is slightly liable to fall off in flakes when first opened, but this liability does not long continue, and, even in galleries many years old, no "creep," or bulging of either sides of floor and roof from pressure is perceptible. No

doubt, this is mainly due to the small depth, the deepest shafts yet opened in this mine being only 160 feet from the surface to the bottom of the coal, while most pits do not much exceed 100.

Tapassi mine.

In Tapassi mine, the whole seam is 22 feet in thickness, from the centre of which 12 feet of coal is mined. The colliery has not been regularly or largely worked until lately. In this case, both roof and sole are formed of coal, which is in general finer and safer than either sandstone or shale. Indeed, in some mines, as at Sirsol, 2 or 3 feet of coal are left in the roof to strengthen it.* Of all the mines above mentioned, the worst conditions for working exist at Rogonáthchuk. Here a 12 feet seam of coal is mined, the roof is of coarse sandstone, very irregular and unsafe, and, despite the relatively large size of the pillars, huge blocks continually fall, sometimes almost blocking up the galleries. The mine is rather deeper than the average, the two shafts at present worked being 138 feet and 148 feet respectively. The mode of working at Harispúr, Mangalpúr, and Chokidánga is similar to that at Rániganj, and the seams worked are similar in thickness.

Tools used.

Except in the one instance of Chinakúri, the tools employed by the workmen are crowbars, hammers of large size, and wedges. In Chinakúri alone, picks are used, but the method of working is altogether bad. The coal, instead of being "holed under," or cut away at the bottom, and wedged down from above, is cut out above, and then broken away from below, mainly by crowbars and wedges. This plan was probably introduced by Mr. Betts; that ordinarily pursued in all mines, except Chinakúri, was

* This is one reason only. Another is, that it has become *customary* to work away a seam of coal not exceeding 10 or 12 feet in thickness. If the coal is thicker, the lower part is subsequently removed from the floor of the gallery. The mode of working employed is best adapted for seams of moderate thickness, and, unless improvements are introduced, a large proportion of the coal in the field will be irrecoverably lost and wasted.

the one originally taught to the native miners by Mr. Jones.* This consists in chipping out a small hollow, by means of the crowbar, near the bottom of the face of coal to be cut away, and then bringing down the coal from above, in blocks of no great size, by means of wedges and hammers. An opening at the side of the end of the gallery being thus made, wedges and crowbars, driven into the joints, bring down the coal from the side of the part cut into. The portion below the hollow first cut is afterwards broken out. Where the gallery is high, the upper part is worked away first, and then the lower portion is wedged out from above. In most mines, where proper supervision is exercised, the galleries are regularly cut, and kept of even width and straight, but in some, under native management, the greatest irregularity prevails, and the miners cut the galleries much as they please, their object of course being to cut coal any how, provided they get out as much round coal as possible.

It is evident that either of these systems of cutting is inferior to the plan adopted in England of "holeing under," that is, cutting with a pick a deep groove at the bottom of the face of coal, then cutting two narrow vertical grooves, and bringing down the mass of coal either by wedges or blasting. It would probably be impossible to trust native miners with gunpowder, which, as there is no fire-damp, and the "roofs" are excellent, might, with careful workmen, be largely and economically employed, but even with wedges, and by using the pick, provided so great a change could by any means be effected in the habits of the workmen, a much larger quantity of coal could, with ease, be cut, and, at the same time, a larger proportion of round coal would

* It is a remarkable circumstance that, although, forty-five years ago, coal mining was unknown in India, the miners have now become so attached to a particular method, and to the employment of particular tools, that they resist the attempt to introduce any alteration as severely as if the innovation interfered with their religious ceremonies. An attempt was made to induce the Chinakúri miners to teach the use of the pick to those of Ráníganj, but the latter rose upon the former, drove them out of the place, and burned their houses down.

be obtained, for, with crowbars, far more coal is broken and crushed than with the pick. It appears surprising that English workmen have never been introduced for the purpose of teaching the native miners in the same manner as has been adopted at iron furnaces in India.

Long wall mode of working.

The "long wall" system of working, (by which the whole breadth of the coal is removed in one face, all being extracted, no pillars left, and the roof being supported behind the workmen by wooden props, which are removed, and the mine allowed to fall in, as the workings proceed,) has not been introduced into India. It unquestionably is by far the best and most economical method, especially with seams of small thickness. In thick seams, a modification of it, which has been employed in Central France, appears well adapted to overcome most of the difficulties presented. This method consists in removing the upper half of the bed first by the long wall system, and then, when the lapse of a few years has reconsolidated the ground, the lower half is removed by the same plan. But, for anything of this kind, greater skill and greater care is necessary in the laborers employed, and, unless the stupidity of the native workmen, and their abhorrence of change can be overcome, which is most improbable, or unless machinery can be introduced for the purpose of cutting coal, there is little chance of any alteration. In seams of coal not exceeding 7 or 8 feet in thickness, there does not appear any good reason, with the great facilities afforded by the shallowness of the mines, and the firmness of the rocks, why the long wall system should not be employed.

The coal, when cut, is carried to the buckets at the bottom of the pits by boys. Trucks are used under-ground in Rániganj colliery alone, and these are pushed by the boys who formerly carried the coal.

The raising is invariably effected in iron buckets or "kibbles," which contain in different collieries from 5 to 7 maunds of coal (410 to 572 lbs.), the most common size being 6 maunds. These are used

as a measure of the quantity of coal cut by the miners, who are paid according to the number of buckets. Chains are generally employed for drawing, but wire rope has been substituted in a few cases. One shaft at Ránigani has been fitted up with guides for raising the coal in the trucks upon which it is brought to the shaft under-ground, but the improvement has not yet been generally employed, even in that colliery. Access to the mines is, in most cases, obtained by an inclined plane cut in the rock.

Method of drawing coal.

In only a few mines are the buckets raised by steam power, although every year the number of drawing engines is increased. In the greater number of collieries, women are employed to drive a "gin," which is merely a modification for hand labor, of the common "horse gin" or "horse whim" of British collieries and metallic mines. The rope passes round a circular wooden drum of the usual form, to the vertical axis of which, at the lower portion, are attached four arms, each of which is driven or pulled by from six to nine women and girls, of whom, from twenty-six to thirty-six, more frequently the latter number, are employed upon one gin. These women are generally the wives and daughters of the miners, and they keep up a peculiar chant while at work. The gin is placed in a building consisting of four brick pillars and a roof, thatched to keep out sun and rain. As usual, two buckets, one ascending as the other descends, are worked either in the same or in different pits by one gin.

The other arrangements at the pit-head present no peculiarities. A wooden platform, running on wheels upon rails, is pushed forward over the mouth of the pit, to receive the bucket on its arrival at the surface. The coal is then generally loaded by hand into ordinary bullock trucks for conveyance to the railway or ghât. In Ránigani mine, the railway has been prolonged to the colliery, and trucks, drawn by horses upon tramways, are used above ground.

Pit-head gear.

Open quarries.

In the open quarries, where coal can be cut out from above, there is naturally much less small coal produced, as all can be split off in large blocks from above by means of wedges, instead of its being necessary to cut under at first. A very common form of mine, however, is a combination of a quarry with under-ground workings. These mines have sometimes been commenced as large open quarries, and when, from the increasing depth of the coal seam, the superincumbent mass of rock and earth becomes troublesome and expensive to remove, galleries were driven in upon the coal, and the ordinary method of under-ground working resorted to for its extraction. In other cases, these quarries have been connected with under-ground workings from the first, and the only essential difference from the method of working by pits is in the raising of the coal, which, from all quarries, is carried out on the heads of coolies, generally women and boys. These combinations of quarries and under-ground workings are termed "undercut quarries" in the following list of mines.

Closed during rainy season.

All quarries are under the disadvantage of being idle for at least five months in the year, from June to October inclusive, as during the rains water accumulates in them more rapidly than it can be removed. A very large proportion of the quarries worked are on the banks of streams, the out-crop of the coal having been exposed in the sections seen in such places, and when, in the rainy season, the streams are flooded, the quarries are frequently filled. In fact, the greater number of the quarries are only worked from the end of December till April or May, that is four to five months in every twelve, the laborers employed in them being occupied, during the remainder of the year, in agriculture, and not commencing to work at coal until after the rice crop is cut.

In many instances, the quarry previously worked is not emptied of

water, and re-worked, after the rains are over, but a new quarry is opened at the side of it, so that the out-crop of many seams of coal is marked by a series of large excavations filled with water. These present, in two ways, serious impediments to deeper workings on the same seam: 1*st*, if there has been under-cutting, there is a risk of tapping the old workings, for no record of their extent is ever kept; and, 2*nd*, the water from the quarries draining through the coal largely increases the quantity in the mine; this has, in some instances, proved so serious an inconvenience, that it has been found necessary to refill the old quarries with earth.

Working the out-crop injurious.

There can be no question that the practice of commencing to work seams of coal by quarries on the out-crop is altogether injurious to the prospects of the mine. The coal is necessarily inferior, and this fact frequently injures seriously the market value of the fuel. It is, however, very cheaply extracted, no expensive machinery being necessary, and only cheap native supervision being required, while the laborers are a class who will not, for the most part, work underground as miners. The dangers of extensive under-ground workings connected with a quarry were, on one occasion, forcibly illustrated at Mangalpúr. The Singáran stream runs past the quarries, one of which was protected by a bank of earth; a sudden rise of the stream breached this, and the water poured into the mine. About twenty-five miners, who were in the deeper workings, were drowned.

Necessity for good plans.

There is much danger of any recollection of the extent to which old workings were carried dying out, and as the system of regular mining becomes largely introduced, the risk of tapping abandoned galleries will be considerable. Even a greater risk, if possible, results from abandoning large mines without careful records of their extent. The number of cases in which this has hitherto occurred is small, and it is most desirable that the

accurate compilation and the preservation of such records should be compulsory.

Steam power.

In a few of the more shallow pits, the water is raised by hand in the same way as in quarries, or occasionally by means of the buckets employed to raise the coal, but in all the deeper mines steam power is used. The steam engines are mostly small, seldom exceeding 25 to 30 H. P., and the majority of the mines, except when first opened, contain but little water. The pumps, two in number, are placed in a quadrangular space cut in the side of the pit from top to bottom. The pump rods are never worked directly from the engine, but are connected by a travelling rod, the greater portion of this, and the whole of the pump rods being formed of sâlwood, with iron fastenings. The diameter of the pumps, and the length of stroke, depending upon the amount of water to be raised, varies in different mines.

Laborers.

The workmen employed above ground and in quarries are mostly agricultural peasants, some being Hindoos or Mussulmáns, but the majority of them belong to the quasi-aboriginal tribes, Bhaúris, Santháls, &c., who form a large proportion of the inhabitants of the district. These races entirely furnish the under-ground workmen, the supply of whom is naturally one of the most important items connected with the establishment of any colliery. Each colliery possesses, either as zemindars (putnidars), or on lease, certain villages, from which its labor is, for the most part, procured. Want of sufficient labor acts largely, even now, in restricting the out-turn of coal, many mines being quite competent, so far as the remainder of their establishment and their machinery is concerned, to raise a considerably larger quantity of coal than they at present produce. During the two seasons in which the survey was carried on, *viz.* 1858-59 and 1859-60, the partial failure of the crops in the Ràniganj or adjoining districts, and the high price of food,

compelled a much larger number of men than usual to have recourse to the mines for subsistence, and this circumstance has, doubtless, largely contributed to the great increase in the quantity of coal raised.

Santhâls, when procurable, are generally preferred to other workmen. They are, however, seldom to be obtained, and, when obtained, rarely remain long in regular employment.

The miner's pay is high. They are paid by the quantity of coal raised, and the usual price paid, in 1859-60, was 5 pice (one anna and three pie) per bucket of 6 maunds of round coal. This has since been increased in some mines, if not in all. A good workman can get out 3 buckets a day, the average is about 2½, giving more than 3 annas a day.* They are not paid for the rubble or dust coal produced. The boys and girls, who carry the coal from the hewers to the pits, and who are employed in picking coal, &c., above ground, receive from 3 to 5 pice (9 pie to 1 anna 3 pie,) the "gin"-women 5 to 6 pie (1 anna 3 pie to 1 anna 6 pie,) according to their age and strength. But they do not obtain this every day, for they keep so large a number of holidays that they only work, on an average, twenty-three days in each month. Allowing for this, a family of a man and his wife, with three children, will earn about 9 Rupees a month, about treble the pay of an ordinary peasant or cooly in the neighboring district. All look well fed, even the children, but otherwise they are little, if at all, improved by receiving better pay than is usually the case with their countrymen. They seldom, if ever, save; they have none of the thrifty habits of the Bengalee, although they have his propensity for running into debt. They are lazy and debauched, their surplus earnings being dissipated in the grog-shop, the invariable appendage to every colliery. The state of morality among them is as low as it can possibly be; in short, they are precisely what might be expected of a nearly savage race, with unusually large pay.

Wages paid.

* I have heard of miners making as much as 9 annas in a day.

Lights used.

The small earthen oil lamps, in the shape of a lipped saucer, commonly used in native houses, are employed to give light to the miners at their work. When more light is required torches are used. Fire-damp is almost unknown, and, consequently, no precautions are requisite. Only one instance has occurred, in which its existence has been observed, a small blower having been cut some years since in Mangalpúr colliery. In the absence of the manager, two men, through their own carelessness, were so severely burnt that they did not survive.*

Value of labor.

In comparing the condition of the coal mines in India with those in Europe, several circumstances must be taken into consideration, one of which, at least, is not peculiar to collieries, *viz.* the comparatively low value of unskilled native labor,† and the high cost of skilled European superintendence. The majority of improvements in Europe tend to substitute machinery for manual labor. In India, the cost of each article differs in an inverse ratio; manual labor is of comparatively small value; machinery,

Cost of machinery.

from the necessity of importation and transport, considerably more expensive than in England. Still, as the demand has considerably outstripped the supply of labor in the Ràniganj district, and as the improvement of railway communication must produce largely increased calls upon the coal field, to meet the wants of Northern and Eastern Bengal, and possibly of Behar, unless the supply of labor can be augmented, improved

* A second instance occurred in the spring of this year (1861) in the East India Coal Company's mine at Parassia, by which two or three men were severely burnt. The connection between the two shafts in this colliery has not been established underground, and, owing to some Native Holidays, there had been no work in progress for a few days, before the explosion took place. There is, however, no reason to anticipate a recurrence of similar accidents, when the ventilation is once established.—T. Oldham.

† There is not probably in India a more remarkable illustration of the low value of human labor than the employment of women to raise the coal from the pits. Any stranger would suppose that bullocks would be much cheaper, but apparently such is not the case, for so obvious a source of power must have been tried.

methods of extraction and the use of machinery must be resorted to for the purpose of economizing it.

Advantages of Ránigañj district.

The mines of Ráníganj enjoy all the advantages of a new district which has as yet scarcely been tapped. Many highly productive seams of coal, doubtless, remain as yet undiscovered, and a large proportion of the field has not even been explored for mining purposes. Borings are now being made pretty generally in the vicinity of the mines, but formerly they were neglected to an absurd extent; so much so, that several cases have occurred, in which pits were sunk, an engine house and the other necessary buildings erected, without the existence of coal having been proved, and, naturally, in some cases,* in places where no coal existed within such depths as have hitherto alone been worked. But far more remains to be done in this way, before the area, over which the seams extend, can be known.

Small cost of pits.

The advantages of a new and rich district are numerous. The abundance of the mineral, near the surface of the ground, renders deep pits unnecessary, hence a great saving of expense in sinking pits and in raising the coal; in machinery for pumping, &c. Another advantage of perhaps equal importance is the absence of fire-damp, and the small number of old and abandoned workings. Immunity from these risks is probably of far greater importance in India than in Europe, since it should be remembered that, careless and ignorant as are the miners in English collieries, it is absurd to compare them with a race like Bhaúris or Santhâls. Unquestionably, were a mine worked in which fire-damp proved abundant, numerous accidents might be feared. And, although there is none or nearly none, in the shallow mines at present working, there is no certainty that the working will be equally free from that same danger, when,

Absence of fire-damp.

* Babúsol, Sathakpúr, Kálastori, &c.

in course of time, the seams near the surface being exhausted, it may become necessary to sink pits to a greater depth. When this occurs, the increased expenditure for sinking pits will induce proprietors to work a larger area from a single pit, or pair of pits, than they now do.

This will produce a considerable change in the circumstances attending the collieries. At present the ventilation is entirely natural, and the large number of pits renders it, in general, very good, but with greater depth, the necessity for good ventilation will increase, especially if fire-damp occurs. If, under these circumstances, the means of natural ventilation are not increased, (and they will, doubtless, on the other hand, be diminished), it will be necessary, both for the health of the miners, and the safety of the mine, to have recourse to some of the artificial methods for passing a current of air through the workings, which are employed in European collieries.

Ventilation.

The liability of the coal of the Damúda field to spontaneous combustion is probably the greatest drawback which exists to its universal employment; otherwise its comparative cheapness would, in a great measure, compensate for its disadvantages in competing with English coal even for marine purposes. It was, for many years, the practice in the various collieries around Ránigani, to leave the small coal, which was, at that time, quite unsaleable, in the mine, and several fires were the result. An account of the conflagration which necessitated the abandonment of the former mine at Ráníganj, in 1842, will be found in Mr. Williams's Report. A portion of the Mangalpúr mine has also been on fire, and the same is the case at Chokidánga, and, probably, at some other mines, in abandoned portions of the workings. An attempt to use small coal as "stoppings" to produce artificial ventilation, once caused great

Drawbacks.

Spontaneous combustion.

Removal of small coal.

danger to the new mine at Ránigunj,* and it has been found necessary, throughout the field, to raise all the dust, shale, and small coal, and to keep the mine perfectly clear. At present much small coal finds a market, being used for brick and lime burning upon the railway, and generally, for buildings, in Bengal; large quantities, however, are thrown away, and heaps are constantly to be seen burning around most of the mines.

Improvements in methods.

Many absurdities in the general system of colliery management are gradually disappearing, as the increased size of the collieries, the value of the property, and the large capital invested, have rendered it advisable to apply greater knowledge and skill to the workings. Until lately, many foolish practices were prevalent. That of commencing from quarries upon the out-crop, and working downward, has already been adverted to. Among other disadvantages, one result of this system was amusing from its absurdity. The pumps were very soon left behind by the work, and, instead of their draining the mine, all the portion below them, upon the dip of the seam, became filled by water. This was generally raised to the pumps by hand labor. This system or want of system was universal a few years since, and may still be seen in some mines. But, in the larger collieries, great improvements have taken place, and some would well bear comparison with English collieries of the same size. Ránigunj mine is the largest and best worked. It has all the advantages of belonging to a wealthy corporation, and of being better situated with regard to railway carriage than any other; its out-turn exceeds that of any other mine, and its workings underground extend for more than half a mile in two directions.

* A portion of the present colliery at Chokidánga took fire early in the present season, 1861, and is still burning (May). This accident has very seriously interfered with the present out-turn of this valuable colliery.—T. OLDHAM.

The above details may serve to convey some idea of the present method of working coal at Ráníganj. The following table has been drawn up in order to show, as far as possible, the present condition and capability of the collieries. The greater portion of the statistics may be relied upon, a few errors may have crept in, but all possible care has been used to eliminate them. The statements of the out-turn of coal are those given by the proprietors of the various mines.

Table of out-turn, &c.

The several columns of the table refer to the following subjects :—

I. The names of the collieries. They are, in general, those of the villages upon the land belonging to which the mine or quarry is situated.

II. The names of the proprietors.

III. The nature of the colliery, whether worked by pits, by quarries, or by the combination already specified as "undercut quarries."

IV. The number of pits and quarries at present at work in each colliery. This, however, varies from year to year.

V. The year in which each colliery was first established. Many have been alternately worked and abandoned several times, and by various proprietors, and in such cases the year when they were first worked, whenever it is known, is that given.

VI. VII. VIII. The out-turn of "round" or large coal for the twelvemonth ending the 30th September, or October, in each of the three years 1858, 1859, 1860. This date is considered the close of the mining season, a custom which originated in the practice of sending all coal to Calcutta by the Damúda River, which is only navigable during the rains. At the time of the river's closing, towards the end of September, the returns of the quantity sent to market could be accurately determined.

In some cases, the returns given, by the proprietors, comprised "rubble" and "dust," or small coal, as well as "round" coal. In such cases, a calculated deduction has been made, and the gross quantity has

been given in the margin. It should be remembered that a very considerable quantity of both rubble and small coal is sold, so that the gross produce of marketable fuel is considerably greater than that given, probably amounting to about one-fifth to one-sixth more.

IX. The number of steam engines, whether for pumping, or pumping and drawing, employed at each mine. No engines are used for drawing alone.

X. The total thickness of the seam of coal on which the workings are carried on.

XI. The thickness of the portion extracted.

LIST of the COLLIERIES worked in the Rániganj Coal Field *during the Years* 1858–59–60, *with Statistics of the Methods of Working employed, Out-turn of Coal, &c., &c.*

Number.	Name of Colliery.	Proprietors.	Method of Working.	No. of Pits or Quarries in work.	Date of first Establishment of Colliery.	Out-turn of "Round" Coal in Maunds for the Year ending September 30th. 1858.	1859.	1860.	Number of Steam Engines and Horse Power.	Thickness of the Coal Seam in feet.	Thickness worked in feet.	Remarks.
						I. Mines in the Singaran Valley.						
1	Chokidánga..	Messrs. Nicol & Sage ..	Pits .. / Quarry ..	2 / 1	1834	330000	485000	264584	2 { 1 of 8 H. P. / 1 of 25 „ }	15½	All	Rubble and dust (1860) 46773—Total 311357.
2	Mámadpúr ..	Bengal Coal Co...	Quarry ..	1	1857	40000	40000	40000	....	14½	All	This Mine was worked in 1857-58-59 by a native, from whom the Bengal Coal Company purchased it in 1859.
3	Dhosul ..	East India Coal Co. ..	Ditto ..	1	1834	....	14000	300000	....	22	All	First worked by Mr. Blake, but long abandoned. Re-worked by the East India Coal Company in 1858.
4	Tapassi ..	Ditto ..	Pits ..	4	About 1848	....	480000		1 of 40 H P.	22	12	Opened by Mr. McSorly. Re-worked from 1858.
5	Jor Jánki (1)	Messrs. Acland and Co.	Under-cut Quarry..	1	1858	....	25000	....	....	5½	All	
6	Ditto (2) ..	Bábú Gobind Prasád Pandit	Ditto ..	1	1858	....	30000	....	....	5½	All	
7	Ditto (3) ..	Bábú Brissonáth Sandil ..	Ditto ..	1	1859	....	....	10000	....	5½	All	
8	Parassia ..	East India Coal Co. ..	Pits ..	2	1859	....	....	30000	1 of 30 H. P.	13?	7	Pits sunk by Bábú Koilásnáth Roi, but not worked for some years. Re-commenced by Messrs. Acland and Company in 1859, and purchased by the East India Coal Company.
9	Mangalpúr ..	Messrs. Erskine and Co. ..	Pits .. / Quarries..	7 / 3	1840	450000	850000	1000000	2 { 1 of 10H.P. / 1 of 25 „ }	15½	All	In the Quarries 9 feet of shale and inferior Coal, overlying the seam, improve in quality, and are worked, making the whole 24½ feet.
9*	Ditto ..	Bengal Coal Co...	Ditto ..	1	1859	....	3600	33000	....	9	All	

LIST of the COLLIERIES worked in the RÁNIGANJ COAL FIELD *during the Years* 1858–59–60, *with Statistics of the Methods of Working employed, Out-turn of Coal, &c., &c.*—(Continued.)

Number.	Name of Colliery.	Proprietors.	Method of Working.	No. of Pits or Quarries in work.	Date of first Establishment of Colliery.	Out-turn of "Round" Coal in Maunds for the Year ending September 30th. 1858.	1859.	1860.	Number of Steam Engines and Horse-Power.	Thickness of the Coal Seam in feet.	Thickness worked in feet.	Remarks.
10	Harispúr ..	Bengal Coal Co...	Pits ..	2	1857	58000	443000	440000	1 of 20 H. P.	17	9	Seam not yet cut through so as to show its whole thickness, it is probably nearly the same as at Harispúr, the bed being identical.
11	Bábúsol ..	Ditto ..	Pit ..	1	1858	....	....	84000	1 of 20 H. P.	17?	9	
						II. Mines in the neighborhood of Raniganj.						
12	Ránìganj ..	Ditto ..	Pits ..	12	1816	1800000	1900000	1600000	6 {1 of 4 H. P., 1 of 6 „, 1 of 10 „, 2 of 35 „, 1 of 25 „}	13	All	
13	Sirsol ..	Bábú Gobind Prasád Pandit	Pits .. / Quarries..	6 / 3	1846	1200000	1600000	1477789	2 {1 of 8 H. P., 1 of 25 „}	20	10 in mine / All in quarry	Gross returns comprising round coal, rubble, and dust, in 1858, Pits...... 1440000 Quarries.. 200000 1859, Pits...... 1800000 Quarries.. 385000 1860, Pits...... 1472125 Quarries.. 184555
14	Rogonáth Chuk ..	Messrs. Erskine and Co.	Pits .. / Quarry ..	2 / 1	1840	100000	175000	300000	1 of 25 H. P.	12½	All	
15	Gopináthpúr or Bansra	East India Coal Co. ..	Pits ..	2	1846	....	180000	70000	....	7	All	Formerly worked by Messrs. Durrschmidt and Company.
16	Bhángaband	Bengal Coal Co...	Ditto ..	2	About 1840	....	60000	250000	1 of 8 H. P.	7	All	Opened by Messrs. Erskine and Company, and worked by Bábú Gobind Prasád Pandit; abandoned for many years. Re-worked in 1858.

17	Nimcha ..	Ditto ..	Ditto ..	1	1859	....	....	70000	1 of 8 H. P.	20	9	A Mine formerly existed in Nimcha in 1846, and was worked by Messrs. Durrschmidt and Company, but it was in a different place from that now worked.
18	Jemeri ..	Bábú Gobind Prasád Pandit	Quarries..	6	1854	250000	400000	364095	....	20	All	Two Pits have been sunk, but no coal has been extracted from them. Rubble, &c. (1860) 29648.
19	Damúlia ..	Bengal Coal Co...	Ditto ..	2	1774? 1824	223000	391000	355000	....	16	All	These Quarries have frequently been worked and abandoned. They have been regularly worked from 1855.
20	Harabhánga	Ditto ..	Ditto ..	1	1859	....	....	150000	....	16	All	
21	Banáli ..	Messrs. Erskine and Co. ..	Ditto ..	1	1860	....	....	30000	....	10½?	All	Boring for future operations. Quarry on the extreme out-crop.
					III. MINES IN THE NUNIA VALLEY, EASTERN DIVISION.							
22	Charnpúr ..	Messrs. Apcar and Co. ..	Pit .. Quarries..	1 1	1851	80000	80000	....	1 of 25 H. P.	13	All	Not worked in 1860. Engine in course of erection.
23	Sámsundarpúr	Bábú Kásináth ..	Pits ..	2	1856	10000	50000	50000	....	13	All	
24	Baraboni ..	Ráni Srinamoni ..	Quarry ..	1	1859	....	....	10000	....	17	All	Out-turn perhaps somewhat higher.
25	Puriharpúr ..	Bengal Coal Co. ..	Under-cut Quarry..	1	1858	....	160000	80500	....	9	All	
26	Mainanagar..	Bábú Debhidin Súkal ..	Quarry ..	1	1848	110000	90000	100000	....	9½	All	
27	Dhadkia ..	Messrs. Erskine and Co. ..	Pit ..	1	1859	....	....	100000	1 of 11 H. P.	9½	All	
28	Sáth Pokaria	Messrs. Acland and Co. ..	Ditto ..	1	1859	....	....	....	....	5	All	This seam was formerly worked to a small extent at the out-crop.
29	Asansol ..	Bábú Ramánáth Bánerji ..	Under-cut Quarry..	1	1857	20000	20000	10000	....	8	All	
30	Sripúr ..	Bábú Rákál Dás..	Ditto ..	1	1859	....	10000	4000	....	7	All	
31	Ninga ..	Bábú Gobind Prasád Pandit	Quarry ..	1	1852	225000	210000	76138	....	7	All	Rubble and dust 7369—Total 83507.
32	Gushik ..	Ditto ..	Ditto ..	1	?	....	50000	17099	....	8	All	There have been Quarries on this spot for many years, 20 at least. Re-worked in 1859.
33	Ditto ..	Tárachander Pál and Co. ..	Ditto ..	1	1856	20000	10000	....	....	8	All	Out-turn, 1860, including Rubble, 18304.
34	Chalwad or Beldángah	Bengal Coal Co.	Ditto ..	1	?	....	....	25000	....	9	All	

LIST of the COLLIERIES worked in the Ránigani Coal Field during the Years 1858-59-60, with Statistics of the Methods of Working employed, Out-turn of Coal, &c., &c.—(Continued.)

Number.	Name of Colliery.	Proprietors.	Method of Working.	No. of Pits or Quarries in work.	Date of first Establishment of Colliery.	Out-turn of "Round" Coal in Maunds for the year ending September 30th. 1858.	1859.	1860.	Number of Steam Engines and Horse-Power.	Thickness of the Coal Seam in feet.	Thickness worked in feet.	Remarks.
			IV. Mines in the Nunia Valley, Western Division.									
35	Gharwi ..	Messrs. Apcar and Co. ..	Quarry ..	1	1855	60000	60000	50000	....	10	All	
36	Barachuk ..	Ditto ..	Ditto .. Pits ..	1 2	1855	60000	60000	70000	1 of 30 H. P.	10	All	Pits not yet in work, engine in course of erection.
37	Fattipúr ..	Ditto ..	Pits ..	2	1858	....	200000	150000	1 of 18 „	10	All	
38	Dhamwa ..	Ráni Srinamoni ..	Quarry ..	1	1855	....	....	20000	....	12	All	
39	Sitarámpúr ..	Messrs. Apcar and Co. ..	Pits ..	....	1847	150000	....	....	1 of 32 H. P.	..	....	Not worked in the years 1859-60, the Engine on the works (of 18 H. P.) not being sufficiently powerful: a larger one now being erected.
			V. Mines in the West of the Field and others not above specified.									
40	Chinakúri ..	Bengal Coal Co...	Pits ..	....	1834	350000	273000	329000	2 { 1 of 20 H. P. 1 of 8 „	$10\frac{1}{2}$	7	On the Damúda—known also as Salánchi Mine.
41	Hatinál ..	Messrs. Erskine and Co. ..	Ditto ..	3	1857	75000	75000	200000	....	$8\frac{1}{2}$	All	Near the confluence of the Damúda and Barákar.
42	* Lálbazár ..	Ditto ..	Ditto ..	2	1857	75000	75000	....	....	$18\frac{1}{2}$	10	East of the Barákar. Not at present working.
43	* Chánch ..	Bengal Coal Co...	Under-cut Quarry..	1	About 1830	141000	260000	....	....	10	All	West of the Barákar.
44	* Núchibád..	Ditto ..	Ditto ..	1	About 1830	....		......	....	10	All	
45	* Dumar-khunda..	Ditto ..	Ditto .. Pits ..	1 1	1858	....	....	280000	1 of 10 H. P.	10	All	
46	Deoli ..	Ditto ..	Under-cut Quarry..	1	1859	....	....	......	....	$4\frac{1}{2}$	All	
47	* Kásta ..	Messrs. Nicol & Sage ..	Under-cut Quarries..	3	1855	90000	60000	38892	....	33	$11\frac{1}{2}$	North of the Adjai. Rubble, &c. (1860) 2525. All worked in places, but when galleries are driven in, only the lowest portion of the seam is extracted.

48	* Ditto ..	East India Coal Co. ..	Ditto ..	1	1849	....	80000	80000	....	35	11½	Ditto ditto, first opened by Messrs. Durrschmidt and Company in 1846. Abandoned for many years.
49	Hirakúnd ..	Ditto ..	Ditto ..	1	About 1840	....	50000	....	....	5	All	South of the Damúda. Hirakúnd was first worked by Messrs. Carr, Tagore and Company.

* Mines thus marked are in the Lower Damúdas—all others are in the Rániganj series.

General Abstract.

		No. of Collieries.	No. of Steam Engines.	1858.		1859.		1860.	
				Maunds.	Tons.	Maunds.	Tons.	Maunds.	Tons.
I.	Mines in the Singáran Valley	11	8	878000	32220	2370600	86994	2201584	80792
II.	Ditto neigborhood of Ránigánj	10	11	3573000	131119	4706000	172697	4666884	171261
III.	Ditto Núnia Valley, Eastern Division..............	13	2	465000	17064	680000	21284	472737	17348
IV.	Ditto ditto Western Division	5	3	270000	9908	320000	11743	290000	10642
V.	Ditto West of the Field and others	10	3	731000	26825	873000	32036	927892	34051
	Total....................	49	27	5917000	217136	8949600	324754	8559097	304094

N. B.—The ton is calculated at 27¼ Maunds.

LIST OF ABANDONED COLLIERIES.

NOTE.—THOSE ABANDONED SINCE 1857 ARE NOT INCLUDED IN THIS LIST.

Name of Colliery.	Proprietor.	Locality.	REMARKS.
Khorabád ...	Messrs. Nicol & Co.	N. of the Adjai ...	A quarry of small extent.
Jainagar ...	A Native ...	S. of the Adjai near Chúralia ...	Ditto.
Dhosul ...	Mr. McSorley ...	Singáran Valley ...	Ditto.
Narrainkúri ...	Messrs. Jessop & Co. & Messrs. Gilmore, Homfray & Co. ...	Near Ránigan j ...	A mine of considerable extent.
Mangalpúr ...	Bengal Coal Co. ...	Ditto ...	A small quarry opened again in 1860.
Nimcha ...	Messrs. Durrschmidt & Co. ...	Ditto ...	Pits, but little coal was got out.
Chinakúri (old)	Mr. Betts ...	On the Damúda 1 mile W. of the new Colliery ...	An undercut quarry of considerable extent.
Deziragarh ...	Messrs. Carr, Tagore and Co. ...	A little W. of China-kúri ...	An undercut quarry.
Lakrajori ...	A Native ...	About 1 mile E. of Lálbazár ...	A small quarry.
Kumardhúbi ...	Indian Coal, Coke & Mining Co. ...	Near Táldángah W. of the Barákar ...	A mine not much worked.
Patlabári ...	Bengal Coal Co. ...	Near Chánch ...	An undercut quarry.
Barmúri ...	A Native ...	On the W. bank of the Barákar ...	Two or three large quarries.
Sángamahál ...	Messrs. Durrschmidt and Co. ...	On the Kúdia S. of Nirsha ...	Quarries.
Núdia ...	Bengal Coal Co. ...	S. of the Damúda and in W. of the field ...	A large undercut quarry.
Marúlia ...	Ditto ...	S. of the Damúda ...	One or two quarries.

There are numerous other places, as Sathakpúr, Kulastori, Ronai, Khatsúli, the ghats at Narrainkúri (Mattrachandi,) Sálma, &c., &c., where pits have been sunk, but either no coal has been found, or it has not been worked.

On the other hand, new pits have been put down or quarries opened at Kajra, Mohuntagram, Alútia, Salburia, &c., but the workings had not extended so far as to bring any coal to market in the year 1860.

The thirtieth of September is given above as the close of the "coal year." This year is closed on the thirtieth of October by some firms, but this makes no essential difference in the returns.

PART III.—ECONOMIC GEOLOGY—SUMMARY.

THE progress of exploration in the Rániganj field has not yet been sufficient to supply materials for a complete list of the coal seams. Such a list was attempted by Mr. Williams, but it will have been seen from the preceding pages, that that geologist was misled as to the position of some of the richest strata, and classed as distinct beds which were of contemporaneous origin. It has also been shown above, that even in the portion of the district which has been most extensively opened out by mines, *viz.* the country in the neighborhood of Rániganj, the knowledge which can be obtained of the relations of the different beds to each other is vague in the extreme. If this is the case where the different mines are only 2 or 3 miles apart, it must be evident, that only surmise can exist as to the identity of coal seams only known at distances of 10, 15, or 20 miles from each other. The seams now worked, and their respective thicknesses, are the following in descending order:—

RÁNIGANJ SERIES.

East of the Field.

Name.		*Thickness in Feet.*	*Also worked at*
1. Sirsol seam	...	20	———————
2. Rániganj ditto	...	14 to 16	Damúlia, Harabhánga.
3. Mangalpúr ditto	...	15 to 20	{ Harispúr, Babúsol. Jemeri? Parassia?*
4. Gopináthpúr ditto	...	7	Bhángaband.
5. Jor Janki ditto	...	$5\frac{1}{2}$	
6. Tapassi ditto	...	22	Dhosal, Banali?†
7. Chokidánga ditto	...	15	Mamadpúr.
8. Rogonáth Chuk ditto	...	12	
9. Chalwad ditto, or Beldangah	...	9	

* This identification is extremely doubtful. † Very doubtful.

West of the Field.

1. Chinakúri seam	...	$10\frac{1}{2}$	Hirakhúnd.
2. Sáth Pokaria ditto	...	$4\frac{1}{2}$	
3. Gúshin ditto	...	8	Asánsol, Mainanagar? Dhadkia?
4. Ninga ditto	...	7	Sripúr.
5. Purihárpúr ditto	...	9	
6. Gharwi ditto	...	10	Fattipúr, Baráchuk.
7. Dhánwa ditto	...	12	
8. Sitarámpúr ditto	...	8	
9. Charnpúr ditto	...	13	Samsúndarpúr, Baráboni?
10. Hatinál ditto	...	10	
11. Deoli ditto	...	$4\frac{1}{2}$	
	LOWER DAMÚDA.		
1. Chánch seam	...	9	Nuchibád.
*2. Dumarkhúnda ditto	...	9	
3. Lálbázar ditto	...	18	
4. Kásta ditto	...	33 to 35	

Thus, in the Rániganj beds, nine seams, (perhaps eleven,) with an aggregate thickness of 120 feet, are worked in the Eastern portion of the field; eleven (perhaps thirteen) seams, amounting to about 100 feet, in the Western portion, and four seams, with a thickness altogether of 69 feet, in the Lower Damúda. But many other seams are known to exist in all these areas, and are enumerated in the preceding pages, while the beds in the Rániganj series, West of the Nunia, may be considered as replacing those East of that stream, although it is by no means certain that any known seams in each locality exactly correspond.

Total thickness of coal.

Before, therefore, any reliable statement can be put forth of the absolute thickness of coal in the Rániganj field, far more extensive underground explorations will be necessary, and as the total available quantity of coal depends, in the first place, upon the thickness of each seam; and, secondly, upon the area underlied by that seam at such a distance beneath the surface, as to be accessible by ordinary mining operations, the problem of ascertaining the whole amount is one for which none of the requisite data are sufficiently exact. It has been conclusively established

* Perhaps Nos. 1 and 2 are the same.

above, that the presence of a seam in one locality in the Lower Damúdas is not sufficient evidence of its extension over the whole area occupied by beds of the same horizon in that series, and although it is possible that the beds of the Ránigani series are continuous over larger districts of country, there is no absolute proof that they preserve their thickness and quality to any considerable distance.

Quality of coal.

The quality of Ránigani coal has at times been much disputed, although long since practically ascertained. One opinion expressed concerning it is, that it consists of a mixture of anthracitic and bituminous coal. This is not correct; the coal is by no means anthracitic, nor is it richly bituminous, but it belongs to a variety of non-coking bituminous coal, with a large proportion both of volatile matter and ash, and the apparent mixture of different kinds of coal is caused by its being invariably composed of laminæ of varying thickness, and consisting alternately of a bright jetty black substance, and of a dull lustreless rock. The brighter portions consist of a very pure coal, a sample of which from Sirsol mine gave the following results on assay*:—

Volatile	40·
Fixed Carbon	57·5
Ash	2·5

This is the composition of some bituminous coals, but contains rather more volatile gases than those best adapted for the production of coke. But there can be but little doubt that, if a seam were discovered, the whole of which showed the above proportions of carbon and ash, a very fair coke indeed could be made from it. An inferior coke may indeed be made from picked specimens of the coal from some of the mines now at work, where the proportion of the bright jetty black layers is large.

* This and the following two analyses are by Mr. A. Tween.

On a close examination the brighter streaks are seen to have a lenticular section. Where thickest, they seldom exceed an inch, and they thin out towards both ends. They appear to be flattened masses of irregular shape, in a matrix of a dull black color. This has not been separately assayed, but the whole mass of the coal, in two *good* samples from Rániganj and Sirsol mines, gave the following results, *viz.*:—

	Sirsol.	*Rániganj.*
Volatile	38·5	36·5
Fixed Carbon	51·1	52·5
Ash	10·4	11·

And the results of a series of assays of various coals on the Ránigan field shows that the above is a fair representation of the composition of the best class of coal obtainable from the mines.*

* The following list gives the average composition of several of the principal coals in the field:—

Indian Coal, Damúda Field.	Carbon.	Volatile matter.	Ash.
Futtipúr	63·80	25·0	11·20
Hatinal	61·0	27·50	11·50
Ránigan	60·50	30·0	9·50
Chowkidangah	56·50	35·0	8·50
Jemeri	55·60	34·0	10·40
Mainanagar, Dhadkia	54·35	35·52	10·13
Gopináthpúr	53·25	35·25	11·50
Tapassi	53·75	31·50	14·75
Sirsol	51·1	38·5	10·4
Rogonáth Chuk	50·50	36·0	13·50
Jor Janki	48·50	30·50	21·0
Nimchah	47·0	31·50	21·50
Mangalpúr	44·75	37·0	18·25
Parasia	44·0	32 0	24·0
Kasta	43·50	32·80	23·70
Harispúr	41·20	37·20	21·60
Mahúldabar	39·20	25·60	35·20

With reference to the above table, it should be stated that probably no second analysis of coals from the same localities would give exactly similar results. They depend much on the sample submitted to examination. And, inasmuch as we could only deal with small quantities, and were compelled to take these at the time of our visit to the mines, all we can assert with reference to the above is, that it gives accurately the composition of fair average specimens of the coals which were being raised for market at each colliery during the years 1859-60. The assays were made by Mr. G. E. Evans.—THOMAS OLDHAM.

Bearing in mind the small quantity of ash in the brighter portions of the seams, it will be at once evident that the quantity in the duller portions must be considerable. It is at least 20 to 30 per cent, so that these duller portions are evidently nothing more than an extremely carbonaceous shale. Hence the value of any coal from Rániganj, or, so far as is known from any Damúda rocks, depends mainly upon the proportion of bright laminæ contained in it.*

The presence of this carbonaceous shale is the main impediment to coke being manufactured from Damúda coal. It is too impure to soften by heat.

The drawbacks to the universal employment of Rániganj coal, and the reason why, despite its greater cost, English coal is still generally employed for many purposes in Bengal, and especially for sea-going steamers on long voyages, may be briefly summed up in the following :—

1*st.* The non-coking property of Rániganj coal.

2*nd.* The small proportion of fixed carbon. The value of a coal for heating purposes varies very nearly as the amount of fixed carbon contained in it.

3*rd.* The large proportion of ash. This and the last mentioned disadvantage may be briefly summed up by stating that Rániganj coal gives a much lower "duty" than any good quality of English coal, and, consequently, a larger quantity is required to do the same amount of work.

4*th.* Its liability to spontaneous ignition. The first three objections to the use of Indian coal need no further remarks. The liability to spontaneous combustion is mainly due to the large quantity of iron pyrites in the coal, and it appears probable that, as the proportion of pyrites varies very much in different seams, coal may be found, by careful selection, to which this objection will not apply, especially if care be taken that the coal is shipped fresh from the mine, and that it is not exposed to the action of moisture.

* The above is, more or less, the case with *all* coals, but the laminæ are far more marked in the coals of India than in those of Europe.

The three most important purposes for which coal is now a desideratum in India are, for railways; for steam vessels; and for the manufacture of iron. For the two first-named purposes, with the important exception of sea-going steamers making long voyages, the coal has been proved, by experience, to be perfectly adequate, and also for the use of stationary steam engines. The objections above mentioned may be considered as only slightly affecting its application to these purposes.

Uses for.

With regard to its application to the manufacture of iron, there does not seem any sound theoretical ground for doubting that, with the better qualities of Rániganj coal, iron can be made in any quantity. The quantity of ash, although large, is not more than in some kinds of Welsh coal, which are used in iron smelting. One great drawback, however, to the quality of the iron will ensue from the proportion of iron pyrites present in much of the Damúda coal.

For iron manufacture.

One element of importance in the manufacture of iron by the blast furnace is the composition of the ash of the coal. Careful analyses were made by Mr. A. Tween, of the Geological Survey of India, of the ashes of the two coals from Ránigaj and Sirsol, the assays of which were stated above, and these analyses show a very unusual composition, *viz.*:—

Composition of ash.

	Sirsol.	*Ránigaнj.*
Silica	48·3	42·0
Alumina	32·4	31·3
Peroxide of Iron	7·5	10·1
Lime	3·5	5·8
Magnesia	1·7	2·7
Alkalies	1·5	1·6
Phosphoric Acid	3·8	2·9
	98·7	96·4*

* The loss, 3·6 per cent., was partly due to carbon remaining in the ash.

The sole peculiarity in the above, affecting the manufacture of iron, is the presence of the very appreciable proportions of phosphoric acid.* For comparison the following analyses of ashes of coal may be taken.†

	Ash in Coal.	Fixed Carbon in Coal.	Silica.	Alumina and Oxide of Iron.	Lime.	Magnesia.	Sulphuric Acid.	Phosphoric Acid.	Percentage. Total.
WELSH COAL.									
Pontypool	5·52	59·3	40·00	44·78	12·00	trace.	02·22	00·75	99·75
Bedwas	6·94	64·8	26·87	56·95	5·10	1·19	7·23	00·74	98·08
Porthmawr	14·72	48·4	34·21	52·00	6·199	0·659	4·12	0·633	97·821
Ebbw Vale	1·50	76·0	53·00	35·01	3·94	2·20	4·89	0·88	99·92
Coleshill	8·92	47·1	59·27	29·09	6·02	1·35	3·84	0·40	99·97
SCOTCH COAL.									
Fordel Splint	4·00	48·0	37·60	52·00	3·73	1·10	4·14	0·88	99·45
Wallsend, Elgin	10·70	47·7	61·66	24·42	2·62	1·73	8·38	1·18	99·99
PATENT FUEL.									
Warlich's	2·91	82·2	25·20	57·30	6·90	trace.	7·85	....	99·41

It will be immediately seen that in Ráníganj coal the proportion of phosphoric acid in the ash is more than double that in any of the above analyses, and as the ash is above the average percentage, the amount of phosphoric acid in Damúda coal, judging from the above analyses, obtained from two distinct seams, is considerable; the percentage of phosphorus being in Sirsol 0·172, and in Ráníganj coal 0·139, the average amounting to 0·155, or between $\frac{1}{6}$ and $\frac{1}{7}$ per cent.

If such coal were used in a blast furnace, a considerable portion of the phosphorus would doubtless be found to combine with the iron produced.

Phosphorus.

The effect of phosphorus upon iron is to render the pig, or cast iron produced very fluid, and slow in solidifying, so that it is, if the quantity of phosphorus be

* In beds so completely destitute of animal organic remains, the presence of so much phosphoric acid is curious.

† First Report on the Coals, &c., suited to the Steam Navy.—*Memoirs of the Geological Survey of Great Britain, Vol. II., Part II., pp.* 550—629.

not too large, well adapted for castings. In the manufacture of bar iron, however, the presence of phosphorus is injurious, as it renders the iron "cold short."

Sulphur.

The effect of sulphur is very different. It renders the pig iron viscid, and much impairs the quality of castings, making them liable to contain flaws and air-bubbles. For the manufacture of bar iron, pig iron containing much sulphur cannot be employed, as the resulting metal is "red short" to an extent which renders it perfectly useless.

The principal objection therefore to the use of Ránigan coal, whether for sea-going steamers or for the manufacture of iron, is the same, *viz.* the presence of iron pyrites. The opinion has already been put forward above, that there are some seams in the Ránigan field sufficiently free from this impurity to be available for both purposes. The attention of coal proprietors in the field may however well be directed to the importance of this point.

Iron Ores.

The iron ores of the country have been largely collected during the progress of the survey. They have already been described with reference to their mode of occurrence, abundance, &c. (*See* ante pp. 74-77.) They comprise, however, besides the clay iron ores, some very rich deposits of magnetic iron, associated with metamorphic quartzite just beyond the south boundary of the field, near the village of Titúri, about 2 miles West of Beharináth Hill. The ore occurs interlaminated with the quartzite and gneiss in bands varying in thickness from 3 inches to 2 feet. They are very pure, and contain from 60 to 70 per cent of iron.

Magnetic Iron.

Clay Iron Ores.

The following list gives the percentage of iron in several different varieties of clay iron ore from different spots on the Ránigan field.*

* These assays were by Mr. G. E. Evans, late Curator of the Geological Museum, Calcutta.

Iron Ores, Damúda Field.	Percentage of Iron.
1. North of Badúl	53·96
2. South of Amnolah	52·00
3. North of Pahargora	51·28
4. South-east of Badúl	50·40
5. Between Birkunti and Ditto	49·33
6. North of Badúl	49·00
7. South of Lynuggur	48·62
8. East of Badúl	47·38
9. Gopalganj	47·35
10. Ráníganj	46·66
11. Near Churalia	44·00
12. Gobinpúr	43·24
13. Near Churalia	42·94
14. Between Birkunti and Badúl	40·99
15. South-east of Madunpúr	40·99
16. Near Churalia	40·46
17. Near Khyrasole	40·81
18. Patachun	40·46
19. Tukri Chuk, East of Kasta ...	39·75
20. East of Badúl	37·97
21. Near Birkunti	34·72
22. Madanpúr	30·00
23. Ditto	29·31
24. Birkunti	27·50
25. Churalia ...	23·00
26. South of Amnola	22·30
27. Birkunti ...	22·00
28. Badúl (Shaft)	14·19
29. Churalia ...	18·00

The several ores are arranged above in the relative order of their percentage of iron. As will be seen, there is a very considerable difference between the several beds, or varieties, and specimens taken from almost the same locality vary from 18·00 up to 44·00 per cent. Compare Nos. 29, 25, 16, 13, 11, &c. If this list be supposed to represent fairly the clay iron stones of the districts, the average percentage of iron would be, as above, 38·92 per cent—a fair and productive percentage.

Average yield.

It should be remembered that the majority of these specimens were obtained at the surface, where the carbonate of iron had been converted by a process of oxidation, into hydrous peroxide. The percentage of iron, however, is but little changed by this process.

The magnetic ores would be available for the purpose of mixing. The ores seem perfectly suited for the production of good iron.

Limestone for flux.

There is much doubt if a sufficient quantity of limestone exist in the district, to be available as flux for large works for an extended period. A large quantity might however be derived from the kunkur deposit on the banks of the Barakur, in the neighborhood of Ramnagar and Boldi, on the left bank, and east of Dumarkhunda, on the right bank, and a smaller amount lies scattered over the field in many places. The subject of limestone has, however, been already treated by Mr. Williams, Mr. Smith, and Dr. Oldham at length, and possibly the extension of the East Indian Railway to the Soane may, in the course of a year or two, enable flux to be brought from the neighborhood of Rhotas at a sufficiently low rate to enable manufacturers in the Ráníganj field to employ it.

Building stones.

Many of the sandstones of the Damúda country might be used to some extent as a building material. The best are the peculiar hard bands in the Ráníganj series, and the somewhat calcareous sandstones occasionally occurring in the lower portion of the Talchir group. Some beds near the top of the Lower Damúda group (as at Bagonia close to the Barakar on the Great Trunk Road) have yielded excellent building stone.

Additional Remarks on the Geological Relations, and probable Geological Age of the several systems of rocks in Central India and Bengal, by THOMAS OLDHAM, L. L. D., F. R. S., &c., &c., *Superintendent of the Geological Survey of India.*

IN a paper published in the second volume of these Memoirs of the Geological Survey of India,* I endeavored to give, so far as known up to the date of that communication (February 1860), a brief summary of the evidence which had then been accumulated, bearing on the very important and very interesting question of the age of the coal-bearing rocks of India; and their associated groups. The additional data which have been acquired during the examination of the Ránigan coal field, reported on in the preceding pages, render it necessary to add here a few words, so as to bring up the facts to the present state of our knowledge.

In the accompanying report (pages 132—137) Mr. Blanford has briefly entered on this discussion with especial reference to that peculiar group of beds,† which he has for the first time separated as a distinct sub-division in the present Memoir, under the name of *Panchet.* And in doing so, he has arrived at a conclusion regarding the age generally of the coal-bearing rocks identical with that previously announced by myself in the paper I have referred to. Indeed, there was little additional evidence to bring to the question, with the exception of the abundant occurrence of an Estheria, believed to be identical with others also found abundantly by the Rev. S. Hislop, in the Nagpúr country at Mangali. These small entomostracous crustaceans having been submitted to the careful examination of Mr. Rupert Jones, of the Geological Society, London, had been identified by him as the *Estheria minuta*

* On the Geological Relations and probable Geological Age, &c.. &c., vol. ii., page 299.

† See also *Journal Asiatic Society of Bengal,* 1860, page 352.

(first figured and described by Goldfuss, as *Posidonia minuta*, Petrefacta Germaniæ, Pl. cxiii., fig. 5) a widely spread and abundant species in the Triassic rocks of Europe and (?) America. Although this fact was of slight importance in itself, it nevertheless tended to confirm all the other evidence, in leading to the conviction that the beds in which it occurred in this country were also of, or nearly of, the same Triassic epoch.

But the discovery of many remains of reptiles in the same group of beds promised to go far towards settling definitely this long agitated question. These had not been carefully examined when Mr. Blanford wrote, and he very justly remarks, that "until these had been examined, it is premature to enter into any further speculations."

When in February 1860, Mr. Blanford first announced to me that he had met with these fossils, and briefly alluded to their character, I at once replied, "are the teeth like Dicynodon? I almost suspect from your brief description of them, that they will prove something of this kind"—remarking also, that I was led to think that these beds would be found to represent the Mangali beds of Nagpúr, an opinion which it will be seen was fully borne out by subsequent examination. I had no opportunity of examining these fossils at that time. I saw a few of them very hastily before leaving Calcutta in March, and certainly saw, among those few, nothing to confirm my suspicion of the occurrence of Dicynodon remains. There were a few teeth, which were apparently true labyrinthodonts, and some vertebræ, which I was more inclined to consider fish vertebræ than reptilian. I left Calcutta almost immediately, and did not return until the end of the year (December.) Meanwhile all these fossils had been brought together and cleared out, and on again going over them with a little more care, I felt quite satisfied that my original conjecture was correct, and that there were Dicynodont remains among them. Knowing, however, how totally incompetent I was to form a critical opinion on such matters, never

having given more than cursory attention to such investigations, I at once despatched the whole collection to my friend, Professor T. H. Huxley, London, and at the same time made arrangements for the further and more complete examination of the beds in which they occurred. This was accomplished by Mr. Tween, (who was originally with Mr. Blanford when these remains were first found,) and the second collection was also subsequently sent to Professor Huxley. Meanwhile I had the pleasure of hearing from him (as he also announced to the Geological Society of London, on the 20th March 1861,) that "the bones belonged to Labyrinthodont Amphibia, and Dicynodont reptiles."

Hitherto no traces of Dicynodont reptiles had been found, excepting in South Africa, and this discovery of similar remains in these Indian beds was of peculiar interest, inasmuch as from considerations based on the evidence of the fossil plants alone, I had been led to refer to these same fossiliferous beds of South Africa, and to indicate the importance of a comparison of their organic remains with those of the Indian rocks.

I was then discussing only the vegetable remains found in the Indian rocks, and said,—" Another district, which will hereafter, when "its fossil plants shall have been worked out, afford many and valu-"able points of comparison, is that richly fossiliferous series of rocks "in South Africa, described by Mr. Bain and others. A cursory "inspection of a few of the fossil plants from that district satisfied me "of the marked resemblance which many of them offered to our "Indian plants." *

Now these are the very beds, the "Karoo beds," or, as they have often been called, the "Dicynodont beds," in which those remarkable remains were found, which, under the skilful interpretation of Owen and Huxley, have added so much to our knowledge of the reptiles of

* *Mem. Geological Survey of India,* vol. ii. p. 327—333.

the earlier Geological periods. Unfortunately, however, even this discovery, all important as it is, does not yet give a *definite* horizon, inasmuch as it is not settled whether these "Dicynodont strata" should be considered Triassic or Permian, and the doubt will (so far as the reptilian evidence goes) still hang over our Indian rocks. But while this may be the case, (and we shall refer to the question again), the evidence seems conclusive, and generally admitted, that these beds containing Dicynodont remains are *not more recent* than Triassic, and inasmuch as their representatives in India are above, and rest unconformably on beds which are, so far as now known, the upper beds of our coal-bearing rocks (the "Damúda" series of our classification) in India, it follows immediately that the opinion hitherto held by most geologists who have written on the subject (McCoy, D'Archiac, Carter, Hislop, &c., &c.), that the coal strata of India were of Jurassic age, must be abandoned.

In the paper previously referred to, I have endeavored to give an idea of the several steps by which I had been led from one point to another in this investigation. I do not think it necessary here to repeat these, but simply to notice that, while I was at first disposed to consider these beds as Oolitic, misled by supposed identifications of plants, (and so misled, until an opportunity occurred for the re-examination of our collections), I also from the first expressed doubts as to the correctness of this view. So long since as 1853,* I said that "some of the fossils have a Triassic aspect, and probably indicate a period a little more ancient than the Oolitic." Again in 1854 (September) I said that we might "*provisionally* consider the coal-bearing rocks of Bengal as belonging rather to the mesozoic than to the palæozoic period"—and as being "probably Oolitic, possibly carboniferous."† This notice of these rocks in a great measure led to the publication of a paper in the same

* Jour. Asiat. Soc. Bengal, vol. xxiii. p. 273.

† Ibid, vol. xxiii. p. 620.

Journal, 'On the age of the coal strata in Western Bengal and Central India', by the Rev. S. Hislop,* in which he strenuously combated this view of the possibility of these coal rocks being older than Oolitic, with great skill and zeal; but with arguments which could have but very little weight, inasmuch as there had been no critical examination of the fossil plants, on which he based his conclusions, and as the supposed resemblance to known species was far indeed from involving identity.

In 1856 again, the Permian analogies of the reptiliferous beds of Mangali were insisted on,† while I stated that no *additional* evidence had been obtained, tending to settle the question one way or the other.

The same palæozoic view of their epoch was again urged more definitely in these Memoirs.‡ And when the establishment of a Museum of Geology in Calcutta enabled me to carefully examine the fossils and to obtain the necessary works of reference for their comparison, I gave at some length the results, as already noticed, in the previous paper referred to, where I have shown that, from physical evidence alone, the Rájmahal group of our classification must be considered as older than the Lower Oolitic stage of European Geology—and that this Rájmahal group is separated by a total change in its flora, accompanied by a strongly marked unconformity attesting the lapse of considerable time, from the Damúda beds below: and that, therefore, these Damúda beds must, in all probability, "belong to some portion of the upper *Palæozoic* division of European Geological sequence, or to the lowermost portion of the Mesozoic division. In fact, we may possibly hereafter find that it will represent that great interval indicated by the marked separation and great break between the two series in other countries."§

Meanwhile other evidence of the occurrence of rocks of an older date

* Jour. Asiat. Soc. Bengal, vol. xxiv. 1855, p. 347.

† Ibd., vol. xxv. 1856, p. 251.

‡ Vol. i., pp. 81-82.

§ *Mem. Geol. Surv. of India*, vol. i., p. 333.

than the Jurassic age assigned to these coal strata had been accumulating. The abundance of *Ceratodus* teeth at Maledi, in the south of Nagpúr, at once determined the horizon of those beds, as nearly, if not exactly, that of the Upper Trias of Europe, while the abundance of *Estheria minuta*,* and the occurrence of the labyrinthodont *Brachyops* at Mangali went far to fix the age of the Mangali rocks, as decidedly older than Oolitic, if not truly Triassic.

I have, however, hitherto in my remarks on this subject commonly avoided any attempt† to bring into correlation beds or groups of beds in other parts of India, which the Geological Survey has not visited, with those in Bengal, excepting in the broadest and most general way. With the experience we already have of how very little has yet been learned of even the physical evidence of these rocks, I believe it to be useless, if not worse than useless, to attempt any very close identifications of rocks, separated by a distance of some 500 miles, the intervening country being quite unknown. I feel perfectly satisfied that every portion of the series will, as facts accumulate, take its proper place in the general series, and I have already said that "great as the delay may be, it is safer and wiser not to hazard any erroneous conclusion by hasty speculation."‡

The Nagpúr country, which will undoubtedly throw much light on these rocks, must be examined by itself, and the relation of its groups of strata to each other determined before they can justly be brought into comparison with those in Bengal. And great as have been the contributions of Messrs. Hislop and Hunter, much, very much yet

* *Jour. Geol. Soc. London*, vol. xii. p. 376.

† Vol. II., p. 334.

‡ I have for this reason avoided insisting on the confirmation of my views, which is apparently afforded by the Ichthyolite beds at Kotah. There is very strong reason for believing these to be above and separated by a very marked break in sequence from the "laminated sandstone" or "Damúda" rocks. And if it be admitted that the Kotah beds are Liassic, it will follow that the others are much older. But we know too little of the relations of these rocks to insist on this conclusion.

remains to be done in this respect.* We have long since noticed that the group A. of Mr. Hislop's series probably was representative of the Mahadeva of our classification,† a view now adopted by Mr. Hislop himself, although partly on independent evidence; we have also noticed the probable identity of his group B. ("laminated sandstone, &c.,) with the Damúda of our series, but with doubts as to whether two distinct groups have not been included in one. But in either case I do not as yet see that there is any conclusive evidence for admitting more than this probability. We rejoice to see that Sir Charles Bunbury has taken up the examination of the plants collected by Messrs. Hislop and Hunter, and we look with great interest for his description. As yet we have only his nominal list of genera and species,‡ but even this seems to us, if the references are borne out by further examination, to bear out the palæozoic age of the rocks. Excluding all those which are Indian (or Australian) *Glossopteris*, &c., we find "*Pecopteris* like *P. Pluckenetii*," '*Nœggerathia*,' *Knorria* (?) *Stigmaria* (?) stem somewhat *Sigillarian* in appearance, "*Yuccites* (?)" a group which certainly has more relations with the carboniferous flora of Europe than with the Oolitic. And the evidence altogether has led Mr. Hislop himself to qualify his opinion as to the age of these rocks, for he now concludes that, on the whole "they probably represent the Jurassic (or possibly the Triassic) period, at all events some portion of the Lower Mesozoic epoch."§

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* We can scarcely reconcile the statement that the upper and laminated sandstones are "conformable," with the evidence of great denudation, and exposure of the lower beds given by the blocks of these beds, containing fossils, found in the upper series.—*Q. J. G. S. L.*, 1859, p. 156.

† I must here protest against the error of Mr. Hislop's statement (*Quar. Jour. Geol. Soc.* London, 1859, June 15th, p. 165), that the term "Mahadeva Sandstone" was introduced by me in any way whatever "to supersede the loose designation of diamond sandstone." The Mahadeva group has nothing whatever to do with the diamond sandstone, is not synchronous with it, and the identity can only have existed in imagination.

‡ Proceedings *Geol. Soc. London,* March 20, 1861.

§ *Ibid.* March 20, 1861.

The marked break between the "Rájmahal," and the Damúda rocks, as proved by the total change in their flora, has now, to a certain extent, been filled up by the establishment, by Mr. Blanford in the preceding report, of the Panchét group or sub-division intermediate between the two. Mr. Blanford has also very clearly shown how the physical evidence of the districts tends to unite this group with the Damúda series below, rather than with any series above it. The unconformity between them is but slight, (in truth such as would never probably have been noticed, were the change from one group to another not marked by a change in mineral character of the rocks,) and the Panchét group has been subjected to the same disturbances and intrusions of trap as the Damúdas below, while the beds above are free from these. Seeing then that while *intermediate* it is physically more connected with the beds below than with those above, it becomes interesting to examine its fossil contents a little more in detail.

We have already noticed the abundant occurrence of *Estheria minuta;* and also the existence of the reptilian remains of Labyrinthodons, and Dicynodons. There remain then only the plants.

The flora of the Panchét beds is, so far as known, very limited, not yielding more than six or eight varieties in all. Of this number there are, *Schizoneura,* 1. *Tœniopteris,* 1. *Sphenopteris,* 2. *Neuropteris?* 1. *Pecopteris?* (2) *Preissleria,* 1. There are a few mutilated and drifted fragments beside, one of which (fragment of one side of a frond) shows the existence of *Glossopteris,* undistinguishable save generically. Of the genera noticed above, *Schizoneura* is one of the most abundant, and is common to the Damúda rocks below, (the species seem distinct.) It is a truly *Triassic* plant in Europe. *Sphenopteris, Neuropteris, Tœniopteris,* are common to both Mesozoic and Palæzoic rocks,* although the latter was more abundant in Mesozoic

* I erroneously stated that Tœniopteris was "only known in Mesozoic and Cainozoic rocks" (Vol. II. p. 320) forgetting at the moment that Gutbier and Geinitz had described it from the *Permian* of Saxony. That paper having been printed during my absence, some few

times. A *Pecopteris* is undistinguishable from *P. concinna* of Sternberg, (Pl. XLI. fig. 3,) a Triassic (Keuper) form. And the curious fossils which we have assigned to *Preissleria* are very similar, if not identical with the *P. antiqua* (Pl. XXXIII., fig. 10, of Sternberg,) also a Triassic (Keuper) fossil. But this flora, although its testimony seems clear enough, would, taken alone, be altogether insufficient on which to base any conclusion. Still it becomes useful inasmuch as the whole amount of its evidence tends to the same result as all the other facts, and thus it gives a cumulative force to all.

Admitting then all this evidence; Dicynodont and Labyrinthodont remains among the vertebrata, *Estheria minuta* in abundance; and peculiar forms of plants identical with some known in European Triassic rocks, I feel no hesitation in expressing my belief that the *Panchét* group of the present report represents the earliest portion of the great Mesozoic division* in the general geological scale, or, in other words, is of about the same age as the *Bunter sandstein* and *Keuper* of Europe. We have in this country, as yet at least, met with no representative of the Muschelkalk, but, as we know from the report of Dr. Fleming, that in all probability it does exist in the Salt Range, Punjab,† it is not impossible that future researches may make known its existence in Bengal or Central India, in neither of which have any marine beds, associated with these sandstones, been as yet met with.

If this be the case, and that the Panchét group does belong to this age, as we conceive has been conclusively established, it remains to consider what are its relations with the beds above and below it.

typographical errors crept in, which were not noticed ; among others (page 320) 'Liassic *Lettenkohlen gruppe* of Thuringia' should have been Triassic.

* I use this term in the sense in which the majority of English Geologists would use it, the line between the Palæozoic and the Mesozoic being supposed to be at the base of the Triassic and above the Permian : but I do not wish to be understood as adopting or rejecting this view, the accuracy of which must be tested by far wider researches than those we are now dealing with.

† Jour. Asiat. Soc., Bengal, vol. xxii. 1853.

In the district at present under description we have no definite group of beds above the Panchét division. I put aside the doubtful sub-group of the "Upper Panchét," which occurs only in detached localities, where the physical evidence of its position is more than obscure; and which, containing no recognizable fossils, can afford no evidence of trustworthy character one way or the other. It is very probable that Mr. Blanford is correct in supposing that these so-called Upper Panchét beds represent the coarse grits and sandstones which occur in the Rájmahal Hills at the base of the Rájmahal group; but this is by no means established.

Below the strata of the Panchét group, we come immediately upon the upper beds of the great Damúda system, the group to which Mr. Blanford has applied the name '*Róniganj*.' Between this Róniganj group, including at its base the Ironstone shales, and the "Lower Damúda" group of Mr. Blanford's report, there is evidence of a slight unconformity and change of both area and condition of deposit. But, independently of this, there are many links of connection, both in the general lithological character of the rocks, in the continuance almost throughout the entire system of large deposits and growth of vegetable matter, now existing in the mineralized condition of coal; and in general stratigraphical relations tending to bind all these groups of beds (having a total thickness of nearly ten thousand feet) into one system, the DAMUDA of my classification.§

But, coincident with this general connection there are most important and most marked proofs of separation into distinct groups. We have spoken of the physical evidence; the palæontological is equally, if not more, definite. Immediately on passing down into the Damúda series, we find abundant representatives of the genus *Glossopteris*, of which no trace whatever has been seen in the "Rájmahal" group, and only one small drifted and broken fragment of a frond in

* Jour. As. Soc., Bengal, vol. 1856, p. 249.

the Panchét rocks. And from these uppermost beds to the very lowest beds of the system, so far as known, these *Glossopteris* remains continue to appear. In the Panchét group a single species of *Schizoneura* is met with, (apparently different from those occurring in the Damúda rocks), and in the upper sub-division of the Damúda system this genus is also largely represented; but we have not seen it from the lower group. *Pecopteris*, *Sphenopteris*, *Phyllotheca*, are also well represented in the upper group of the Damúda system, but are almost entirely wanting in the lower. We have not as yet been fortunate enough to find any organic remains other than vegetable in these rocks. The evidence seems, therefore, abundant to lead us to group all these sub-divisions ("Ŕániganj," "Ironstone shale," and "Lower Damúda") into one system, but not sufficient as yet to define the epoch of this system. On the one hand it is connected by the occurrence of a single genus of plants common to both, with the Triassic strata of Panchét, on the other it is widely separated by the general *facies* of its flora, which is far more abundant and varied, as well as by the break in continuity of deposition. The Damúda system is then older, probably considerably older, than the Triassic epoch of the Panchét group. It exhibits a thickness of several thousand feet, marked at intervals, during the tranquil deposit of this enormous mass of material, by the successive growths of luxuriant vegetation and thick masses of ferns and other plants. And it *must* represent the lapse of a very long period of time, and great changes in general conditions of the area during that period.

I am, therefore, led to think from all this, that the "Damúda system" of our Indian classification will be found to represent, (if not in its entirety, certainly in part) the Permian period of European geology.* But I think further, that it will be found also to include a

* The "*Dyas*" of Marcou. While fully appreciating the skill with which M. Marcou has set forth his opinions, and while agreeing with him, as will be seen, as to the age of these rocks, I do not adopt all his reasons for this proposed change of names.

large portion of the Upper Carboniferous epoch. Indeed, although the data on which to base an opinion are still deficient both in number and exactitude, it would seem probable that the southern hemisphere, even the southern portion of the northern hemisphere, will be found to supply, in great part, those wanting links in the chain, those gaps in the succession of organic existences, which are so marked in Europe.

It has long been known that the Indian coal-bearing rocks (the Damúda system) contained many fossils identical with those found in the coal rocks of Australia, and that this series of stratified deposits in both these countries was therefore, synchronous. The age of these coal rocks in Australia has itself been the subject of much contention, and is not as yet by any means finally settled. To these rocks I have already referred elsewhere,* and have endeavored to draw from the analogy of these Australian beds some evidence bearing on our Indian coal beds. We can now, I believe, reflect the light derived from our Indian series on the Australian succession; and can so far remove the doubt which hangs over the question of their age, as to fix conclusively a period more recent than which they *cannot* be.

I may take this opportunity of noticing briefly a few facts bearing on these rocks. Through the kindness of His Excellency Sir William Denison, now Governor of Madras, I had recently the advantage of receiving a small but excellent series of specimens from the neighborhood of Sydney, prepared at Sir William Denison's request by Mr. W. Keene, Examiner of Coal Fields, Newcastle, N. S. W., for the Geological Survey Museum, Calcutta, and accompanied by an admirably drawn and detailed section showing the exact position from which each specimen was obtained. This series contained specimens from the rocks both above and below the coal-bearing beds of the section. I was surprised on examining this series of specimens not only to find, as I had expected, a perfect identity in the contained

* Memoirs Geological Survey of India, Vol. II., p. 330.

plant remains with those with which I was familiar from India, but further a very remarkable and strikingly curious identity in the lithological character and structure of the rocks themselves; this identity being by no means confined to one of the groups of beds, but having a marked persistence in all. Thus the fine-grained, earthy, fawn-colored sandstones and shales in which the remains of *Phyllotheca* and *Glossopteris* abound in the Australian rocks are precisely such as might, from mineral character, be supposed to have been taken from the upper beds of Central India, (the "Upper Damúda" of Mr. Medlicott): the coal itself presents identically the same laminated texture, the surface of the laminæ thickly covered with mineral charcoal, or the half fossilized remains of woody-tissue; and still more curiously, the same very peculiar curved jointing giving rise to that remarkable "ball" structure (see above) as in the Indian coal of the Ràniganj Field; and this, in just as great perfection in the Australian coals. And still further, many of the lower beds of the Australian group, there so abundantly rich in marine fossils, are very similar to many of the beds in the Indian *Talchir* series. There is the same mixture of pebbles, and large rolled masses in a matrix of fine silt; and much of this silt is of exactly the same peculiar blueish-green tint, so characteristic of these beds in this country, and which, once seen, can never be mistaken.

I would not be misunderstood as desiring to give any great weight to a similarity in mineral texture or lithological aspect, in attempting to ascertain the true position of these rocks. But I am satisfied that this identity has a value, and by no means a light value, when, taken in connexion with every other point of evidence which is available, it is found in all cases tending to turn the balance in the same direction. And, basing my views on these considerations, I ventured* to hold out a prospect in anticipation, that future researches would enable a more

* Jour. As. Soc., Bengal, May 1861.

accurate and detailed parallelism to be established between the rocks in both these countries, portions of which were now known to be synchronous: and that, while in all probability, it would be found, that starting from the common datum line of the coal-bearing rocks in either land, the sequence upwards would be established from Indian researches in this country, apparently supplying links wanting in Australia; on the other hand we should be enabled to supplement the evidences of the succession downwards (which is deficient in India) by a reference to Australian groups. As yet we have not been able to trace the existence of any marine deposits in this country, of the same age as the "Wollongong" sandstones of Australia, but there is nothing whatever in the few plants which occur in our Talchir beds which would militate against their being of the same general age, (which I am disposed to think they are).

But such speculations are, perhaps, premature, and I have no doubt whatever that, as our detailed investigations progress, each successive group will find its appropriate place.

But it is certainly not by any forced assimilation, or any narrow parallelism with *European* types that this end is to be gained. Each country, each district, each basin, must be examined by itself, and for itself, and long before the slightest attempt at any true identification of the smaller sub-divisions or beds can safely be made we must have a far wider, and a far more accurate, knowledge of the stratigraphical relations, and of the geographical area, of each of the larger systems.

And even then we must never forget that we are dealing with the remains of animals and plants which once lived in countries, separated from the typical localities with which we attempt to correlate them, by half the surface of the globe; that there were as truly zoological and botanical provinces in earlier periods of the earth's history as there are now: that the atmosphere, the elevation, the climatal conditions

generally, of each locality exerted as powerful and controlling an influence then as now, and that, therefore, while we seek for and probably obtain resemblances, or even identities, in these tropical and subtropical remains, as compared with the European types, we *must* also be prepared to see vast differences, and marked discrepancies.

I have only to add a few words on the nomenclature adopted by Mr. Blanford.

The term Panchét, the name of a remarkable hill, the name also of a *raj* or estate, on which this hill stands, and the title of the Rajah who now holds much of this country, and whose ancestors once held almost it all, serves well to denote the peculiar group of rocks which occurs there. The name of Ràniganj, also, the well known terminus of the East Indian Railway, situated close to the largest mines in the district, and on the Ràniganj series, serves well for that group. While the *Talchir* series has been already well defined from the locality where first it was separated, as a distinct group, from the overlying rocks.

There remains the term "Lower Damúda." The group to which this term has been applied has been very well separated by Mr. Blanford, but I fear the name itself is open to objections, which render it desirable to alter it. Mr. Blanford has himself shown the inconvenience of names derived from relative position only, especially where the whole series in detail is not known, in the case of the "Upper Damúda." And the term Lower Damúda is open to similar objection. It is more than probable that future research will fill up the gap now existing between the lowermost beds of this Lower Damúda and the Talchir rocks, (indeed, I believe, that these intermediate beds are to a certain extent already known,) and should these intermediate beds be found to belong to the Damúda system, there would then be a group lower than the "Lower Damúda. I think it, in every point

of view, wiser and better to adopt the same course with this group as with the others, and to give to it a name derived from some marked locality where it occurs. And, inasmuch as the bank and the immediate neighborhood of the Bárákar river exhibit excellent and characteristic sections of this group, I would substitute for "Lower Damúda" the name "Bárákar group."

To prevent any misconception, I would add here that the excellent remarks of my colleague on the value of the coals from this 'Lower Damúda' group, must be taken as applicable only to the field immediately under consideration, in which the almost universal intrusion of trappean rocks into these lower coal beds would alone be sufficient to account for the inferior quality of much of the coal. The Kurhurbari coal beds, are, however, all in 'Lower Damúda' rocks, and the coal is fully equal to any found in the Raniganj field, while at the same time there is evidence of the occurrence also of the lower beds of the upper series in the same field.

I would also take advantage of the present opportunity to state that more recent researches have given to Mr. Medlicott from his "Upper Damúda" rocks of Central India, many varieties of fossil plants, of which no specimens had been procured from these beds up to 1860, and which go far to prove that these groups in Central India must be referred to the Damúda system, and not to the Rájmahal. So marked indeed is the resemblance of the flora of these rocks from the vicinity of Sohagpúr to the true Damúda flora, (*Glossopteris, Phyllotheca, &c.,*) that I am almost led to suspect, although the fact may not at first be traceable, that these will be found to be a different group of beds from those first called Upper Damúda, and the plant remains in which were so markedly different from those known in the ordinary coal-bearing rocks of India. While, therefore, I think it will be desirable to get rid of the term 'Upper Damúda,' as applied to a sub-division of a series or system, the true limits of which are not yet known, I

believe we still want very much more satisfactory fossil data before we would definitely refer the rocks which have been called Upper Damúda to any fixed parallel in the rocks of Bengal.*

The age of the Mahadeva group, referred to by Mr. Blanford, I would abstain from discussing at present, as I feel convinced that there are as yet no sufficient data on which to base any satisfactory conclusion.

CALCUTTA, *June* 1861.

* In speaking of the fossils of these rocks in Volume II. of these Memoirs, I mentioned (p. 324,) a number of what seemed to be the "detached scales or bracts of the cones of cycadeous plants." Shortly after writing that, some better specimens were procured, which led me to think them rather coniferous than cycadeous.

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INDIA.

MINERAL STATISTICS.

I.—COAL.

THE accompanying returns give as full and complete data regarding the actual amount of coal raised throughout India generally as I have been able to procure. It is not supposed that a first attempt of this kind may be free from errors, or mistake. All that can be expected is, that all proper precautions have been taken. In this respect I may state that, with the exception of the smaller workings in the Ránigaṇj field, the produce of which was obtained at the pits themselves, and with all possible precaution of repeated enquiry and cross questioning, the amounts given below are those stated to me under authority of the several proprietors, agents, or secretaries of Companies, &c., and these proprietors thus become responsible for the accuracy, each of his own return.

There are still a few collieries known to be at work, from which I have not succeeded in obtaining any return. These are those at Kotah, Singrowli, &c.: but the out-turn of these is known to be small, and would not seriously affect the general result.

The returns are given for three years past, that is, from the 1st of October or November 1857, to the same date 1860. This is, by custom, considered the close of the "coal year," from the circumstance that, until recently, the only mode of conveyance for coal from the Ránigaṇj field was by the River Damúda, and as the accounts were closed, when, after the rainy season, the river had so diminished in the amount of its waters, that there appeared no chance of sending any

more coals to market that season—this period thus became the customary close of the local year.

The total returns give an average out-turn of coal for the past three years of 87,37,454 maunds, or about 320,631 tons. But it is scarcely just to consider this as giving a fair mean of the present out-turn, for during the first of these years there were, as is well known, disturbing causes at work tending to injure the regular trade of the country—and a fairer average, though determined by too small a number of years, will be obtained by taking the mean of the last two year's produce. This will give 100,25,020 maunds, or about 367,890 tons in the twelve months.

The returns also show one important and interesting fact, namely, that however the local out-turn may have increased or diminished, as affected by local causes, the general out-turn has steadily and markedly increased, apparently indicating a healthy and sound extension of trade and commerce.

The total out-turn for 1860 (that is, for the twelve-months ending October 1860) was 100,88,113 maunds, or 370,206 tons, an amount almost contemptible (about the 200th part) if compared with the wondrous total of the coals raised annually in Great Britian, *viz.* 72 millions of tons! But still evidencing a large and increasing commerce and the spread of many of the arts of civilization.

To the table a few notes have been appended, referring to other parts of the country where coal is either known not to occur, or where it may have been found in small quantities, but is not workable.

The tables commence with the details of the Rániganj coal field, by far the most productive as well as important coal field in India, and the other localities are referred to afterwards.

LIST of the COLLIERIES worked in the RÁNIGANJ COAL FIELD *during the Years* 1858–59–60, *with Statistics of the Methods of Working employed, Out-turn of Coal, &c., &c.*

Number.	Name of Colliery.	Proprietors.	Method of Working.	No. of Pits or Quarries in work.	Date of first Establishment of Colliery.	Out-turn of "Round" Coal in Maunds for the Year ending September 30th. 1858.	1859.	1860.	Number of Steam Engines and Horse-Power.	Thickness of the Coal Seam in feet.	Thickness worked in feet.	Remarks.
						I. Mines in the Singaran Valley.						
1	Chokidánga..	Messrs. Nicol & Sage ..	Pits .. / Quarry ..	2 / 1	1834	330000	485000	264584	2 { 1 of 8 H. P. / 1 of 25 ,, }	$15\frac{1}{2}$	All	Rubble and dust (1860) 46773—Total 311357.
2	Mámadpúr ..	Bengal Coal Co...	Quarry ..	1	1857	40000	40000	40000	....	$14\frac{1}{2}$	All	This Mine was worked in 1857-58-59 by a native, from whom the Bengal Coal Company purchased it in 1859.
3	Dhosul ..	East India Coal Co. ..	Ditto ..	1	1834	....	14000	300000	....	22	All	First worked by Mr. Blake, but long abandoned. Re-worked by the East India Coal Company in 1858.
4	Tapassi ..	Ditto ..	Pits ..	4	About 1848	....	480000		1 of 40 H. P.	22	12	Opened by Mr. McSorly. Re-worked from 1858.
5	Jor Jánki (1)	Messrs. Acland and Co. ..	Under-cut Quarry..	1	1858	....	25000	....	....	$5\frac{1}{2}$	All	
6	Ditto (2) ..	Bábú Gobind Prasád Pandit	Ditto ..	1	1858	....	30000	....	....	$5\frac{1}{2}$	All	
7	Ditto (3) ..	Bábú Brissonáth Sandil ..	Ditto ..	1	1859	....	....	10000	....	$5\frac{1}{2}$	All	
8	Parassia ..	East India Coal Co. ..	Pits ..	2	1859	....	....	30000	1 of 30 H. P.	13?	7	Pits sunk by Bábú Koilásnáth Roi, but not worked for some years. Re-commenced by Messrs. Acland and Company in 1859, and purchased by the East India Coal Company.
9	Mangalpúr ..	Messrs. Erskine and Co. ..	Pits .. / Quarries..	7 / 3	1840	450000	850000	1000000	2 { 1 of 10 H. P. / 1 of 25 ,, }	$15\frac{1}{2}$	All	In the Quarries 9 feet of shale and inferior Coal, overlying the seam, improve in quality, and are worked, making the whole $24\frac{1}{2}$ feet.
9*	Ditto ..	Bengal Coal Co...	Ditto ..	1	1859	....	3600	33000	....	9	All	

LIST of the COLLIERIES worked in the RÁNIGANJ COAL FIELD *during the Years* 1858-59-60, *with Statistics of the Methods of Working employed, Out-turn of Coal, &c., &c.*—(Continued.)

Number.	Name of Colliery.	Proprietors.	Method of Working.	No. of Pits or Quarries in work.	Date of first Establishment of Colliery.	Out-turn of "Round" Coal in Maunds for the Year ending September 30th. 1858.	1859.	1860.	Number of Steam Engines and Horse-Power.	Thickness of the Coal Seam in feet.	Thickness worked in feet.	Remarks.
10	Harispúr ..	Bengal Coal Co...	Pits ..	2	1857	58000	443000	440000	1 of 20 H. P.	17	9	Seam not yet cut through so as to show its whole thickness, it is probably nearly the same as at Harispúr, the bed being identical.
11	Bábúsol ..	Ditto ..	Pit ..	1	1858	....	....	84000	1 of 20 H. P.	17?	9	
				II. Mines in the neighborhood of Raniganj.								
12	Ràniganj ..	Ditto ..	Pits ..	12	1816	1800000	1900000	1600000	6 {1 of 4 H. P., 1 of 6 „, 1 of 10 „, 2 of 35 „, 1 of 25 „}	13	All	
13	Sirsol ..	Bábú Gobind Prasád Pandit	Pits .. / Quarries..	6 / 3	1846	1200000	1600000	1477789	2 {1 of 8 H. P., 1 of 25 „}	20	10 in mine. All in quarry	Gross returns comprising round coal, rubble, and dust in 1858. Pits .... 1440000 Quarries .. 200000 1859. Pits .... 1800000 Quarries .. 385000 1860. Pits .... 1472125 Quarries.. 184555
14	Rogonáth Chuck ..	Messrs. Erskine and & Co. ..	Pits .. / Quarry ..	2 / 1	1840	100000	175000	300000	1 of 25 H. P.	12½	All	
15	Gopináthpúr or Bansra	East India Coal Co. ..	Pits ..	2	1846	....	180000	70000	....	7	All	Formerly worked by Messrs. Durrschmidt and Company.
16	Bhángaband	Bengal Coal Co...	Ditto ..	2	About 1840	....	60000	250000	1 of 8 H. P.	7	All	Opened by Messrs. Erskine and Company, and worked by Bábú Gobind Prasád Pandit; abandoned for many years. Re-worked in 1858.

17	Nimcha ..	Ditto ..	Ditto ..	1	1859	....	....	70000	1 of 8 H. P.	20	9	A Mine formerly existed in Nimcha in 1846, and was worked by Messrs. Durrschmidt and Company, but it was in a different place from that now worked.
18	Jemeri ..	Bábú Gobind Prasád Pandit	Quarries	6	1854	250000	400000	364095	....	20	All	Two Pits have been sunk, but no coal has been extracted from them. Rubble, &c. (1860) 29648.
19	Damúlia ..	Bengal Coal Co...	Ditto ..	2	1774? 1824	223000	391000	355000	....	16	All	These Quarries have frequently been worked and abandoned. They have been regularly worked from 1855.
20	Harabhánga	Ditto ..	Ditto ..	1	1859	....	....	150000	....	16	All	
21	Banáli ..	Messrs. Erskine and Co. ..	Ditto ..	1	1860	....	....	30000	....	10½?	All	Boring for future operations. Quarry on the extreme out-crop.
					III. Mines in the Nunia Valley, Eastern Division.							
22	Charnpúr ..	Messrs. Apcar and Co. ..	Pits .. / Quarries	1 / 1	1851	80000	80000	....	1 of 25 H. P.	13	All	Not worked in 1860. Engine in course of erection.
23	Sámsundárpúr	Bábú Kásináth ..	Pits ..	2	1856	10000	50000	50000	....	13	All	
24	Baraboni ..	Ráni Srinamoni ..	Quarry ..	1	1859	....	....	10000	....	17	All	Out-turn perhaps somewhat higher.
25	Puriharpúr ..	Bengal Coal Co...	Under-cut Quarry..	1	1858	....	160000	80500	....	9	All	
26	Mainanagar..	Bábú Debhidin Súkal ..	Quarry ..	1	1848	110000	90000	100000	....	9½	All	
27	Dhadkia ..	Messrs. Erskine and Co. ..	Pits ..	1	1859	....	....	100000	1 of 11 H. P.	9½	All	
28	Sáth Pokaria	Messrs. Acland and Co. ..	Ditto ..	1	1859	....	....	....	....	5	All	This seam was formerly worked to a small extent at the out-crop.
29	Asansol ..	Bábú Ramánáth Bánerji ..	Under-cut Quarry..	1	1857	20000	20000	10000	....	8	All	
30	Sripúr ..	Bábú Rákál Dás..	Ditto ..	1	1859	....	10000	4000	....	7	All	
31	Ninga ..	Bábú Gobind Prasád Pandit	Quarry ..	1	1852	225000	210000	76138	....	7	All	Rubble and dust, 7369—Total, 83507.
32	Gushik ..	Ditto ..	Ditto ..	1	?	....	50000	17099	....	8	All	There have been Quarries on this spot for many years, 20 at least. Re-worked in 1859.
33	Ditto ..	Tarachander Pál and Co. ..	Ditto ..	1	1856	20000	10000	....	....	8	All	Out-turn, 1860, including Rubble, 18304.
34	Chalwad or Beldángah	Bengal Coal Co.	Ditto ..	1	?	....	....	25000	....	9	All	

LIST of the COLLIERIES worked in the Rániganj Coal Field *during the Years* 1858-59-60, *with Statistics of the Methods of Working employed, Out-turn of Coals, &c., &c.*—(Continued.)

Number.	Name of Colliery.	Proprietors.	Method of Working.	No. of Pits or Quarries in work.	Date of first Establishment of Colliery.	Out-turn of "Round" Coal in Maunds for the Year ending September 30th. 1858.	1859.	1860.	Number of Steam Engines and Horse-Power.	Thickness of the Coal Seam in feet.	Thickness worked in feet.	Remarks.
			IV. Mines in the Nunia Valley, Western Division.									
35	Gharwi ..	Messrs. Apcar and Co. ..	Quarry ..	1	1855	60000	60000	50000	....	10	All	
36	Baráchuk ..	Ditto ..	Ditto .. / Pits ..	1 / 2	1855	60000	60000	70000	1 of 30 H. P.	10	All	Pits not yet in work, engine in course of erection.
37	Fattipúr ..	Ditto ..	Ditto ..	2	1858	....	200000	150000	1 of 18 „	10	All	
38	Dhamwa ..	Ráni Srinamoni ..	Quarry ..	1	1855	....	....	20000	....	12	All	
39	Sitarámpúr ..	Messrs. Apcar and Co. ..	Pits ..	....	1847	150000	....	....	1 of 32 H. P.	..	....	Not worked in the years 1859-60, the Engine on the works (of 18 H. P.) not being sufficiently powerful: a larger one now being erected.
			V. Mines in the West of the Field and others not above specified.									
40	Chinakúri ..	Bengal Coal Co...	Pits ..	....	1834	350000	273000	329000	2 {1 of 20 H.P. / 1 of 8 „}	$10\frac{1}{2}$	7	On the Damúda—known also as Salunchi Mine.
41	Hatinál ..	Messrs. Erskine and Co. ..	Ditto ..	3	1857	75000	75000	200000	....	$8\frac{1}{2}$	All	Near the confluence of the Damúda and Barákar.
42	* Lálbazár ..	Ditto ..	Ditto ..	2	1857	75000	75000	....	....	$18\frac{1}{2}$	10	East of the Barákar. Not at present working.
43	* Chánch ..	Bengal Coal Co...	Under-cut Quarry..	1	About 1830	141000	260000	....	....	10	All	West of the Barákar.
44	* Núchibád..	Ditto ..	Ditto ..	1	About 1830	....		......	....	10	All	
45	* Dumar-khunda..	Ditto ..	Ditto .. / Pits ..	1 / 1	1858	....	....	280000	1 of 10 H. P.	10	All	
46	Deoli ..	Ditto ..	Under-cut Quarry..	1	1859	....	....	......	....	$4\frac{1}{2}$	All	
47	*Kásta ..	Messrs. Nicol & Sage ..	Under-cut Quarries	3	1855	90000	60000	38892	....	33	$11\frac{1}{2}$	North of the Adjai. Rubble, &c. (1860) 2525. All worked in places, but when galleries are driven in, only the lowest portion of the seam is extracted.

48	* Ditto ..	East India Coal Co. ..	Ditto ..	1	1849	....	80000	80000	....	35	11½	Ditto ditto, first opened by Messrs. Durrschmidt aud Company in 1846. Abandoned for many years.
49	Hirakúnd ..	Ditto ..	Ditto ..	1	About 1840	....	50000	....	....	5	All	South of the Damúda Hirakúnd was first worked by Messrs. Carr, Tagore and Company.

* Mines thus marked are in the Lower Damúdas—all others are in the Ráníganj series.

General Abstract.

	No. of Collieries.	No. of Steam Engines.	1858.		1859.		1860.	
			Maunds.	Tons.	Maunds.	Tons.	Maunds.	Tons.
I. Mines in the Singáran Valley	11	8	878000	32220	2370600	86994	2201584	80792
II. Ditto neighborhood of Ráníganj	10	11	3573000	131119	4706000	172697	4666884	171261
III. Ditto Núnia Valley, Eastern Division	13	2	465000	17064	680000	21284	472737	17348
IV. Ditto ditto Western Division	5	3	270000	9908	320000	11743	290000	10642
V. Ditto West of the Field and others	10	3	731000	26825	873000	32036	927892	34051
Total	49	27	5917000	217136	8949600	324754	8559097	304094

N. B.—The ton is calculated at 27¼ Maunds.

LIST of COLLIERIES worked in the RAJMAHAL HILLS, *and other places in India, during the Years* 1858-59-60, *with Statistics of the Methods of Working employed, Out-turn of Coal, &c., &c.*

Names of Collieries.	Proprietors.	Method of Working.	No. of Pits or Quarries.	Date of first Establishment.	Out-turn of Round Coal for Year ending 30th September.			No. of Steam Engines and Horse-Power.	Thickness of Seam in feet.	Thickness of Seam worked.	Remarks.
					1858.	1859.	1560.				
					RAJMAHAL HILLS. *Brahmini Nuddi and Neighborhood.*						
Hurrinsingah	H. Wilson, Esq. (deceased) ..	Quarry ..	2	1854 '55	48000	....	....	....	13	13	Not worked after 1858.
Mussinia ..	Messrs. Avdall, Knott and Co.	Under-cut Quarry..	1	1860	....	....	....	....	......	....	
Domunpúr ..	C. J. Hampton, Esq. ..	Quarries	2	1860	....	....	2343	....	4	4	
Sursabad ..	Ditto ..	Ditto ..	3	1859	....	....	75517	....	3	3	
Panchbynee ..	Messrs. Mackey and Co. ..	Under-cut Quarry..	1	1857	36000	60000	14000	....	7	7	Coal in 1860 only raised for private use at Mahomed Bazar Iron Works.
Ghatchora ..	Ditto ..	Quarry ..	1	1858	8000	....	....	....	3	3	
Domanpúr ..	Ditto ..	Ditto ..	1	1859	....	30000	8000	....	3	3	Not worked since 1858. Coal inferior.
					Bansloi Nuddi and Neighborhood.						
Gopikandur ..	H. Wilson, Esq. (deceased) ..	Quarry ..	1	1856	7000	....	....	....	......	....	
Oormoo ..	Messrs. Eaton & Browning	Quarries	2	1858	....	26000	30000	....	7 and 3	All	About one-third of the total out-turn of these Quarries consisted of rubble coal.
Koondapahar	Ditto ..	Ditto ..	1	1858	5000	10000	1000	....	3	3	
Chilgo ..	Ditto ..	Ditto ..	1	1858	5000	10000	20000	....	5	All	
Bankijora ..	Ditto ..	Ditto ..	1	1858	10000	45000	30000	....	19	19	In parts of Quarry only 11 feet are cut.
Burgo ..	Ditto ..	Ditto ..	....	......	....	....	....	....	......	....	Not now worked.
Ditto ..	C. H. Barnes, Esq. ..	Quarry ..	1	1859	....	6000	....	....	7	All	Only 1800 maunds carted to the Ganges: cost of carriage being too great.

Goomani Nuddi and Neighborhood.											
Teesaphuli ..	P. Burke, Esq. ..	Under-cut Quarries	2	1856	100000	150000	210000	....	11	8	Trial shafts being sunk.
Ghutkum ..	Ditto ..	Pit ..	1	1859	....	....	50000	....	16	16	
Simlón ..	C. H. Barnes, Esq. ..	Quarry ..	1	1860	....	....	8000	....	3 to 8	All	2700 maunds only removed: expense of carriage being too great.
North-West of Hills.											
Lohundia ..	Paturghatta Lime Co. ..	Drift ..	1	1859	....	....	86000	....	9	9	
Hurrah ..	East Indian Railway Co. ..	Under-cut Quarries	2	1857	......	420000	700000	....	14	14	
Bora ..	Ditto ..	Under-cut Quarry..	1	1858				....	17	17	
KURHURBARI COAL FIELD.											
Kurhurbari ..	East Indian Railway Co. ..	Pits ..	12	1858	4000	108182	275256	4 H.-P.	7 to 16	7 to 16	
Ditto ..	Bengal Coal Co...	....	....	......	....	....	....	....	......	....	Not working.
PALAMOW COAL FIELD.											
Palamow ..	Bengal Coal Co...	Quarry ..	....	......	....	28648	30900	....	......	....	No detailed information.
KHASIA AND JYNTEAH HILLS.											
Cherra ..	Messrs. Moran and Co. ..	Quarries & Drifts ..	....	......	10253	18731	....	....	4 to 6	4 to 6	
Lakadong ..	Ditto ..	Ditto ..	150	1839–40	12066	13767	....	....	4 to 6	4 to 6	
SINGROWLI AND REWAH.											
Kota ..	....	....	....	......	....	....	....	....	......	....	No return.
SCINDE, LYNAH VALLEY.											
Lynah Valley	Scinde Railway Co. ..	Pits ..	4	1857	45300		....	....	5′ 9″	....	Cannot be considered a colliery: the coal is in irregular patches of variable size.

General Abstract.

DISTRICTS.	1858.	1859.	1860.
Raniganj Coal Field	5917000	8949600	8559097
Rajmahal Hills	219000	843000	1222860
Kurhurbari	4000	108182	275256
Palamow	......	28648	30900
Sylhet Hills	22319	32498	......
Total in Maunds	6162319	9961928	10088113
Or in Tons	226140	365575	370206

Of the Singrowli coal field, which lies to the south of the River Sone, in the Rewah Territory, I have not been able to procure any return. I am, however, aware that the amount of coal raised has been small, and will not materially affect the general total. More than one bed of coal has been practically examined in the continuation of this field to the west and towards Singhpoor. But none of these are as yet at work as collieries.

The Nerbudda Valley has long been known to contain coal, but owing to the distance from any available market, and the comparative inaccessibility of the localities where it occurs, it has not been hitherto economized. The Nerbudda Coal and Iron Company have this year commenced their operations and I suppose will shortly be turning out coal.

In other parts of the North-Western Provinces territory there is no known *workable* coal. Seams of lignite of very irregular size and very limited extent occur in several places along the foot of the Sub-Himalayas, marking a certain group of sandstone rocks, of comparatively recent date; but nowhere are these deposits known to be of extent rendering it probable they will ever be of any practical use.

In Oude no coal is known to occur. In the Punjab no coal is known to occur, if we except, as above in the North-Western Provinces, the patches of lignite which have been found in several localities along the base of the outer Himalaya, as well as in the Salt Range.

In Scinde the only coal raised was that of Lynah Valley, as given above, but the irregularity and the small extent of this deposit has caused it to be abandoned. It was, in fact, an irregular patch of *lignite.*

In Bombay no coal is known to occur. In Hyderabad none. In Nagpore a small coal field is known near to Umret, on the border of the Nerbudda District, which may, in fact, be considered a

continuation (although actually separated) of the Nerbudda deposits. The coal is not now economized.

In Madras no coal is known. Coal has been more than once stated to occur on the Godavery, or some of its feeders. And even very recently; but as yet nothing but black shales, which will not support combustion, and which are, in all probability, of a totally different age from the coal-bearing rocks of India, have been met with.

T. OLDHAM,
Supt. of Geological Survey of India.

Calcutta, 1*st June* 1861.

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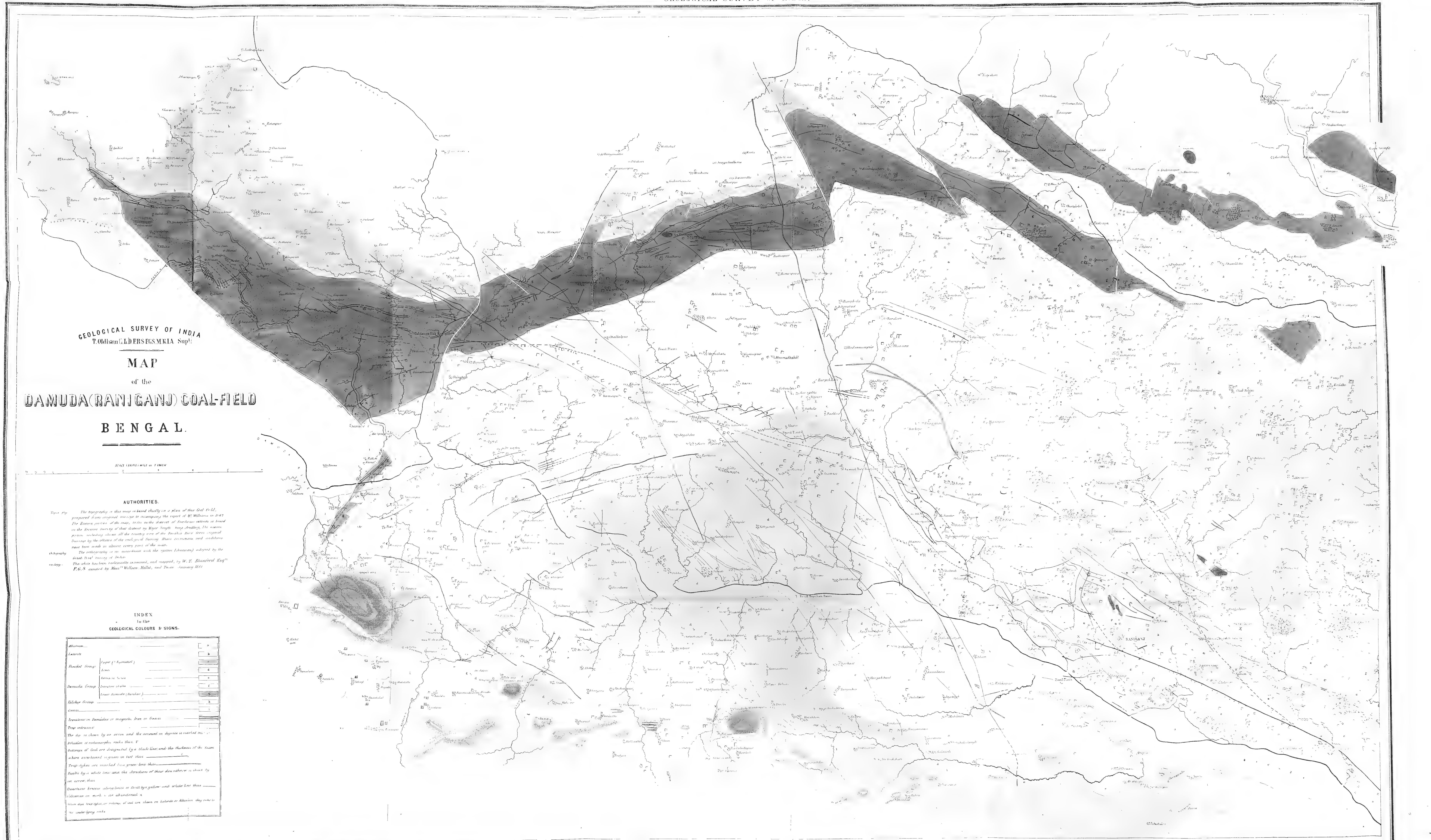

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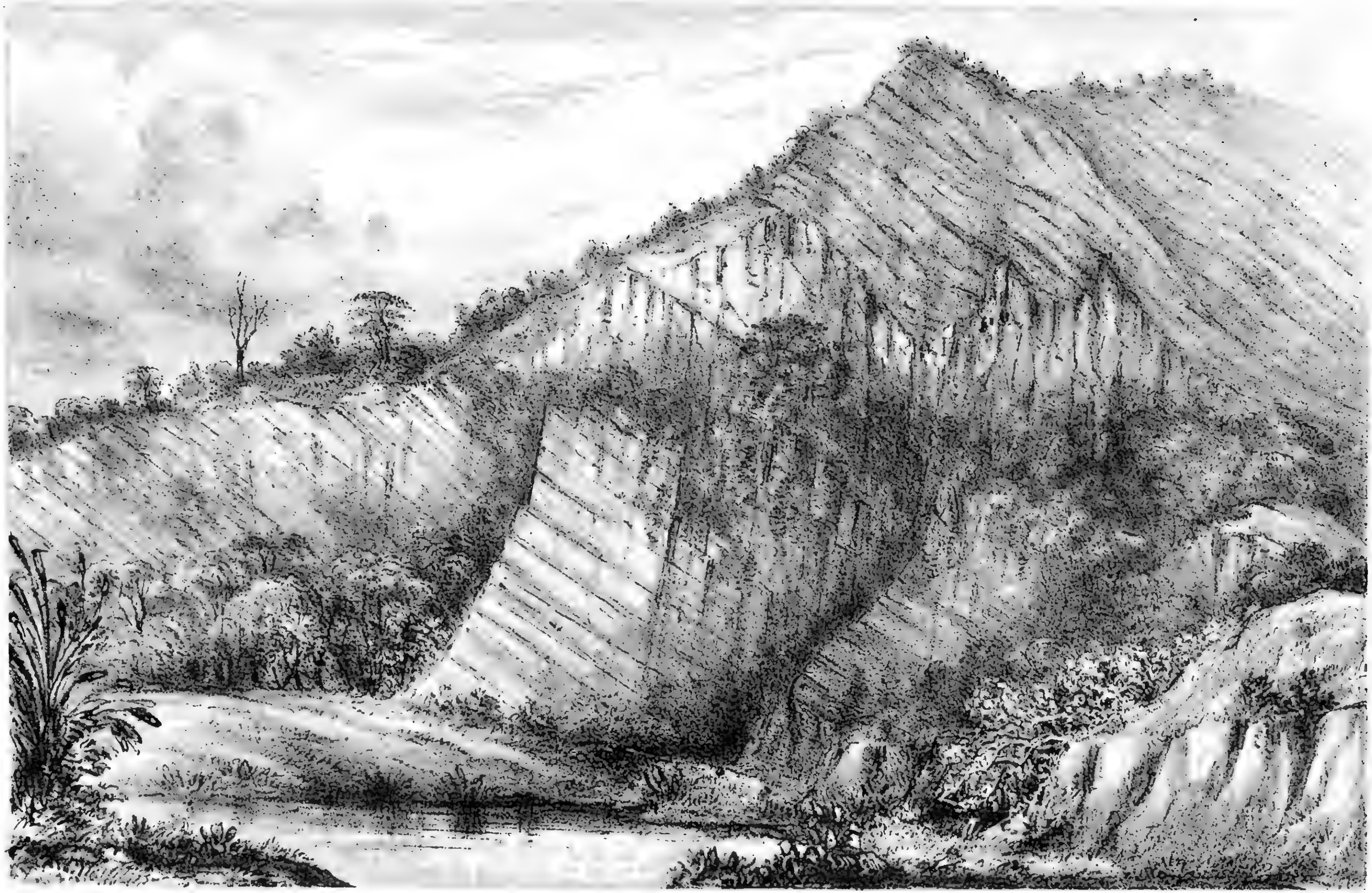

H.L. Frazer Lith:

JUNCTION OF THE SIVALIK AND NAHAN GROUPS
IN THE MARKUNDA.

Calcutta

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the Geological structure and relations of the Southern portion of the HIMALAYAN *range between the rivers* GANGES *and* RAVEE, *by* H. B. MEDLICOTT, A. B., F. G. S., *Geological Survey of India.*

CHAPTER I.—*General description of area and rocks.*

A TREATISE of which the Himalayas form the subject bears on its title-page a sufficient recommendation to a large class of readers. Many causes, mythical as well as scientific, have tended to spread, even among popular readers, a deep and general interest in all questions relating to the physical history of this portion of the globe. The follow-

Special object.

ing memoir is, primarily, a record of geological observations; but, as a work of systematic geological observation could not be carried on without implicating many questions in physical geography and other kindred sciences, this report treats also of these subjects *in so far as they appear to be connected with the geology of the district.* There must necessarily be many imperfections in a work which has been conducted on a very limited scale, when compared with the whole region involved; and general conclusions must be considered as more or less premature which are hazarded upon a partial review of facts. While I would claim a generous indulgence for these imperfections,—imperfections which depend on the scanty state of our knowledge of the Himalayas,—I would remind the reader that I also make them an apology for introducing many facts

which may appear at first sight unimportant, trifling, or irrelevant, feeling, as I do, that such facts may afterwards supply valuable evidence, when investigations have been extended over a wider range.*

In deciding on a plan for the extension of the Geological Survey into North-Western Hindustan, there were two courses prominently open for selection. Already the fossil fauna of the Sivâlik hills, brought to light by Cautley and Falconer, had created a deep and enduring public interest in the geology of the southern slopes of the Himalayas; and, more recently, the valuable labors of D'Archiac and Haime in the palæontology of the Nummulitic strata, including those of Subathu, had given additional attractions to the same regions. In opposition to these strong inducements to begin with the Himalayas there was the well ascertained fact that the original stratification of the formations composing these mountains had been much complicated by disturbances. Judging from this fact that insurmountable difficulties would present themselves at every step in the attempt to elucidate the physical history of the Himalayas,—and it will be seen in the following pages that this surmise was well founded,—it was resolved that the country beyond the great plains which stretch southwards from the base of the Himalayas should be examined first. It was considered probable that the structure and relations of the rocks composing this extensive and comparatively plain tract of country were much more simple than in the mountain regions, and it was hoped that thus some clue might be discovered to the complicated geology of the latter. Accordingly I was deputed in 1856-57 to survey Bundelcund and parts of the adjacent country, and the great Vindhyan formation was then traced from Rewah, where it is typically developed, into the country towards Gwalior. The result of this work has been published in the form of a memoir in the

* In order to elucidate my observations upon the obscure question of mountain formation, I have given in an appendix a brief summary of the most prominent opinions with regard to it.

second volume of the "Memoirs of the Geological Survey of India." In the following seasons it was intended to carry on this work towards Delhi, and through the country to the south and west of that city, but in 1857 the mutiny broke out, and for two successive seasons it was impossible to visit that part of the North-Western Provinces for the peaceful purposes of field geology. The hills, however, were comparatively secure, and to them accordingly the attention of the Survey was temporarily directed. The great series of tertiary strata, of which the Subathu beds form the base and the Sivâliks the top, was chosen as the special object of investigation, because these rocks had already excited so much public interest ; and the excellent map of a large section of the North-Western Himalayas, which had just been published by the Surveyor General, offered rare facilities for pursuing successfully the geology of this portion of the hills.

In endeavouring to add to the valuable knowledge of the geological relations of the Sub-Himalayan regions, with which palæontologists have supplied us, I have almost exclusively attended to the questions of lithology and stratigraphy, because up till this time little or nothing had been known of the nature of these relations, though some of the rocks have been so well known from the fossils which they have yielded.

Area described.

The area included in the accompanying map, and to the description of which this memoir is more particularly devoted, is contained between the Ganges on the south-east and the Ravee on the north-west. The direct length of this tract of country is about 230 miles ; its width varies from twenty to sixty miles, the average being at least thirty ; so that the entire area is about 7,000 square miles. Although equal in length to that of the base of the Pyrenees on the French side, this area does not represent more than a sixth part of the entire range of the Himalayas. In addition to the description of the Sub-Himalayan zone, included in the accompanying map, I shall have some observations to record upon the rocks that bound this great tertiary

series on the north-east; and also on the extension of all these rocks towards the south-east to Naini Tal, near the frontier of Nepal, and towards the north-west to Murree, near the extreme frontier of British India. On account of the advantages offered to health-seekers, as well as on account of the physical peculiarities of these hills, they have always attracted crowds of visitors. The oldest and the most fashionable of our Indian hill-stations, or sanitaria, are in the region I have indicated. Simla occupies a nearly central position between the Ganges and the Ravee; between Simla and the plains are the military depôts of Subathu, Kasaoli, and Dugshai; Masuri lies more to the south-east, near the Ganges; and to the north-west there are Dhurmsala, and the now rapidly increasing station of Dalhousie. Besides, some of the most accessible routes to the Tibetan regions, beyond the snowy passes, lie through these hills, and from numerous descriptions that have been given of this country from time to time by tourists, it has become almost as well known as many familiar regions in Europe.

Eastern and Western Himalaya.

On every physical map of India will be found the remarkably regular line which indicates the north boundary of the plains of Northern Hindustan. From the dead level of these plains the Himalayan region rises as from an ocean. The effect of this contrast is, I think, rather heightened than diminished by the great distance of the culminating points of the range; the extent of panorama visible at a short distance from the base of the range is thereby greatly increased, and the imagination seldom fails to allow for the great distance of the principal objects of the landscape. The extreme regularity of the outer boundary of the mountain region is maintained from the Brahmaputra to the Jhelum, but we do not find a corresponding uniformity in the features *within*, or to the north of this boundary. At about the middle of the distance just indicated, and which also happens to be the middle of the district under description, there is an entire change in the characters of the hills and in the distribution of the rocks. The

distinction of Eastern and Western Himalaya is familiar to many ; it is not, as some may think, an arrangement of simple convenience, nor yet, as has been argued, is it a question to be settled from mere hypsometrical data. It is a change of which the full significance in the structure and history of the mountain system cannot yet be determined, but the facts I will point out seem to indicate that the range (under the stricter definition of this term) to which the peaks of the Eastern Himalaya belong, ceases or rather becomes subordinate here, and is not to be identified with any such chain of peaks to the north-west, excepting as independent members of the same system. Regarding the Western Himalaya, I have only indirect remarks to make ; the Eastern Himalaya are essentially the snowy mountains of Hindustan. They present, as a whole, three well marked regions :—the range of peaks ; then a broad band of hills commonly spoken of as the Lower, or Outer, Himalaya ; and outside or to the south of these comes a narrow fringing band of much lower hills, for which the name *Sub-Himalaya* is appropriate, and of which the Sivâlik hills are the type.

Lower Himalaya.

The Lower, or Outer Himalaya exhibit no approach to a regular gradation of elevation. From within ten to twenty miles of the peaks to about an equal distance from the plains the hills have a very uniform aspect and elevation. They average from 7,000 to 9,000 feet in height, in some exceptional cases rising to 10,000, or even 12,000 feet. The peak of the Chor, about twenty-five miles to the south-east of Simla, is one instance of this higher elevation close upon the outer limits of the region. The Naini Tal hills too, near the very edge of the plains, are considerably higher than the ridges for some distance to the north-east of them. Herbert describes this feature more minutely. He says :—" If we divide the country south of the line of greatest elevation into five parallel zones, the fifth will be as high as the third, and the fourth considerably lower than either." The form and general direction of the ridges throughout the Lower Himalaya is a question of much importance in relation to the *structure* of the whole

mountain system; I will here only call attention to the fact—as indicated on the map by the features of elevation and of drainage—of how strongly the denudation type of hill-contour is stamped upon the Lower Himalaya region,—a type characterized by the close recurrence of irregular ridges and equally irregular river courses, *transverse* to the general direction of the mountain region. They are watershed-ridges only. As a rule, I fail to trace even the guiding influence of simple fissures, in any definite system, in pre-determining the lines of drainage.

The scenery of these hills presents, generally, great sameness,—a monotony of steep slopes, and ridges of almost uniform height, and with little variety of outline, only occasionally relieved by a bold cliff or a rocky gorge. Not unfrequently also forests of magnificent trees are met with, no longer of those tropical forms which are associated with the intense heat of the lower country, but with all the aspect familiar to travellers in the more temperate regions of Europe. These forests stand almost invariably on the northern slopes of the ridges,—a peculiarity of position which is no doubt principally due to the greater moisture of the sunless aspect favouring such a vegetation; the southern slopes, however, have no doubt been extensively cleared artificially for the purposes of cultivation, and for village sites.

The outer limit of the Lower Himalaya is generally a very marked feature. Along it the change is a rapid one to hills of much less elevation, and of different aspect. As a general rule, the hills of this zone attain only very moderate elevations, but they exhibit a striking uniformity of arrangement; they are true hill-ranges,—members proper, though very subordinate, of the great Himalayan system. Their regularity in this respect forms a strong contrast with the arrangement of the Lower Himalaya ridges. The ridges of the Sub-Himalayan zone are approximately coincident with lines of disturbance, being usually formed by anticlinals, or on the upthrow side of faults; the intervening depressions, forming the longitudinal valleys, are locally known as *duns*. The

scenery of the Sub-Himalayan hills has few attractions. Near the gorges of the great rivers, or where the view opens out upon the *duns,* and the higher hills beyond, the landscape is often striking ; but among the hills themselves the range of vision is generally limited to a few yards ; the only paths are along the beds of torrents, hemmed in either by sheer walls of rocks, or by steep banks densely covered with jungle.

Snowy peaks.

The snowy peaks of the Eastern Himalaya form by no means so regular a range as might be supposed. They form groups of summits along a culminating zone, rather than any approach to a regular ridge. This feature has been well described by Herbert, Strachey, and others.

Contrast between Eastern and Western Himalaya.

The most opposite views have been put forward as to the relations of the Eastern and Western Himalayas. Captain Herbert, in his mineralogical survey of the Himalaya, is strangely confused in this matter of ranges. He lays down the Simla ridge as the proper continuation of the Eastern snowy range, consistently giving as his criterion the fact of its being the watershed of the Sutlej and the Ganges ; yet, in speaking of the other transverse ridges, parallel to the Simla ridge, he says :—"Like the principal chain they cease suddenly, nor is there any trace either in the Doab or in Rohilcund of a continuation of them, however obscure" (Jour. As. Soc., Ben., No. 126, p. 17). Adopting wider views on the subject, but still only such as are within the ken of the physical geographer, Colonel Cunningham considers the Bara Lacha range, bounding Chumba and Kashmir on the north, as the continuation of the 'true' Himalaya (Cunningham's 'Ladak,' p. 42). If such relations as those of drainage system, ethnography, climatology, &c., are to be the criteria in determining the continuity of these ranges, east and west, this view is no doubt correct, for these in a great measure depend upon the one unquestionable fact that the Bara Lacha range *is* the culminating ridge. But not even this latter fact is of much weight in establishing the inference that these

two ranges are one and the same member of the great Himalayan system,—a signification which the word 'true' ought to convey; indeed, it is the only sense in which the word 'true' can here be made use of; for, as I have said, the mere fact of orography cannot be questioned. The whole question gives an apt illustration of how distinct are the views of the geologist and the physical geographer, or even of how incongruous the latter may be among themselves. Each of these writers is correct upon the *bonâ fide* basis which he adopts. From the geological point of view it may be doubted whether the question of *identity* can be entertained at all: the transverse *ridges,* such as that of Simla, are eliminated as being superficial only, and among the true *ranges* each may either be an independent member of the general system, or, relations of homology may be established between them. The complete change that takes place in the configuration of the mountain region suggests some radical difference of conditions. This contrast could not escape the notice of so acute an observer as Colonel Cunningham. Notwithstanding his identification of the two snowy ranges, he says, in the work already referred to, "there is one marked difference between the Eastern and Western ranges which can scarcely fail to strike the most casual observer. The inferior mountains of the Eastern chain generally run at right angles to its axis, whereas those of the Western range are mostly disposed in subordinate parallel ranges." The same facts may be illustrated by saying that the hills of Chamba exhibit in a marked manner orographical features depending on the symmetry of elevatory action, while in the hills lying to the south of the Eastern Himalaya there is seen an equally close approximation to that type of hill outline which results from denudation alone. No doubt, the actual contours in both cases are the immediate results of denudation, this result in each case having been influenced, or even predetermined, by the succession of previous subterranean phenomena. In the Lower Himalaya the ultimate or present configuration has been the result of denuding forces alone, in

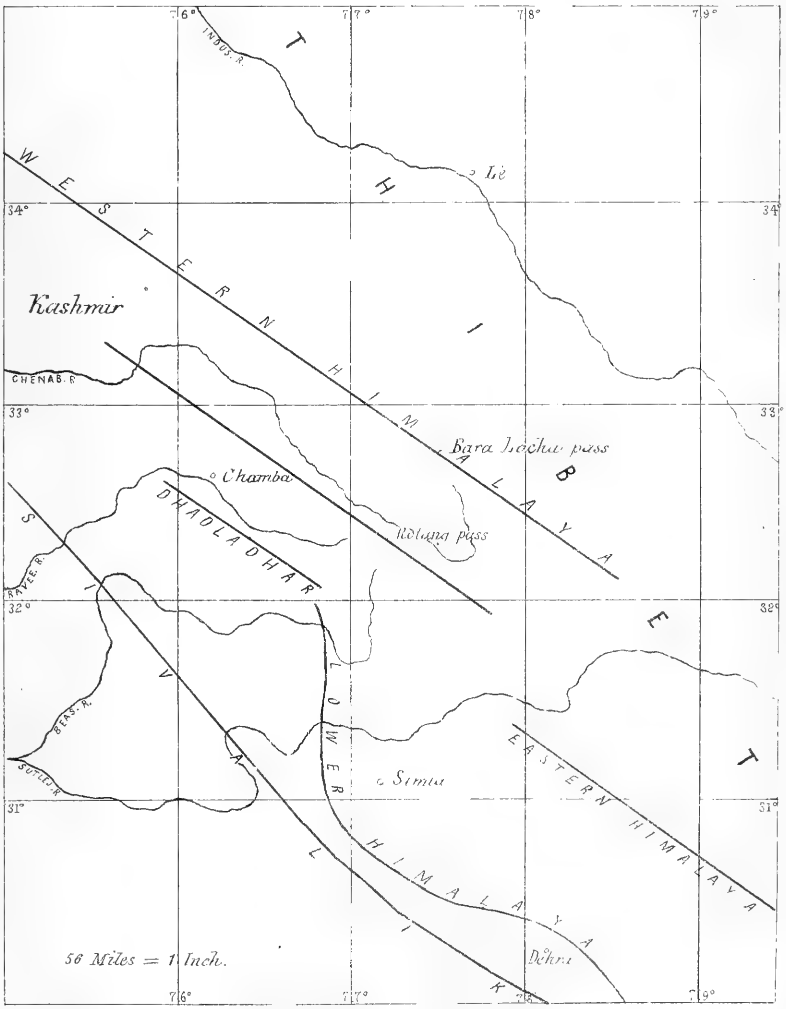

Fig: 1. SKELETON PLAN Shewing the position and relations of the main ranges of the HIMALAYA, between the degrees of Longitude of 75° and 79°.30′. E.

consequence of the absence of any dominant or marked lines of elevation. This region is one of comparatively neutral disturbance, whereas, in the ridges of Chamba, we have strongly marked structural characters which I conjecture to be the attenuated, yet locally concentrated, result of the causes which produced the culminating zone of the Eastern Himalaya. The Dhaoladhar range is in the direct continuation of the Eastern Himalayan range, and is, I conceive, its true representative. We will see how very different its structure is from anything known in the Lower Himalayan region. But whatever views may ultimately be adopted regarding the true equivalence of these several chains of the Himalayan system, the structural peculiarities of the outer region of the Eastern Himalaya, and the external configuration resulting therefrom will require special explanation. The annexed diagram (Fig. 1) exhibits clearly in outline the features to which I am now drawing attention, and the remarkable manner in which the Sub-Himalayan region is affected by the changes of the greater mountain-features. To the east of the Sutlej this region forms only a very subordinate fringing belt, while to the west it expands over a wide area; the outer or southern boundary undergoes little or no modification in direction, but northwards the Sub-Himalayan hills stretch to the very base of the Dhaoladhar, thus occupying the position corresponding to that of the region, which, more to the east, is specially designated the Lower, or Outer, Himalaya. The lines of disturbance are graduated with considerable regularity between the straight outer boundary and the sharp curves of the inner boundary (*vide* larger map). West of the Beas there is no equivalent for the Lower Himalayan region, as described to the east of that river.

Two series of rocks.

Before entering upon the details of the stratigraphical features, I would indicate the general facts. In 1860 I submitted to the Asiatic Society of Bengal an abstract of the results I had up till that date arrived at. Although much new ground

has been examined since then, as well as old ground revisited, the views I then expressed have undergone but slight modifications. From end to end of our map we find two series of rocks strongly contrasting in composition. It is only provisionally that I speak, collectively, of the inner and older of these series. It comprises limestones, shales, sandstones, slates, grits, quartzites, schists, and gneiss,—an assemblage offering ample room for classification; but I have as yet only conjectures to offer as to their mutual relations. These conjectures will be placed together in a separate chapter. I will frequently refer to these rocks throughout the following memoir under the indefinite names of Inner and Older rocks. The outer rocks, on the contrary, form a well marked geological series or system, although composed of several distinct groups and sub-groups. In honor of the most distinguished of these groups, I might designate the whole as the Sivâlik series; the details of its characters would be found to justify this name, but, on the whole, and as not involving an idea of geological age, I think the more general term of Sub-Himalayan series will be more suitable.

Base of Sub-Himalayan series.

With one exception, the newer, and the older rocks are separated throughout by a well marked boundary, along which they are in vertical contact. The contrast is striking to the least skilled geologist, and there can seldom be any hesitation in judging from the relative conditions of the two rocks which is the older. Such a junction, however, would be a most unsatisfactory horizon, or rather no horizon at all; it would leave the question of the original relations of the two series quite uncertain. The exception to which I allude clears up this question in the most satisfactory manner. Over a considerable area about the middle of our map, nearly occupying the whole length between the Sutlej and Jumna, there is to the north and east of this marked boundary line an outlier of the Sub-Himalayan series. We here find the base of the series, and its original junction with the underlying rocks,—a true geological horizon. The bottom beds

of this outlier rest on a denuded surface of the older rocks, and have been folded up with them in the same contortions.

Subathu group.

Although I have only mentioned this outlier as exhibiting the lowest member of the Sub-Himalayan series, it contains in itself a well-defined group or formation of considerable importance, both in vertical thickness and horizontal extent, and admitting of two or three sub-divisions, no one of which can be strictly identified with beds of the higher groups to the south of it. These statements will be appreciated when I say that the Nummulitic strata of Subathu, which have so much contributed to bring this region into notice, form but a portion of this outlier,—the lowest member of these sub-divisions being thus the bottom beds of the whole Sub-Himalayan series. The prevalent character of the Subathu beds is calcareo-argillaceous,—thick beds of silty clay, generally of subdued neutral colours, of very fine texture, and weathering in splinters, both acicular and sub-cubical, very rarely shaly, or even laminated. The calcareous element shows most frequently in irregular, sub-concretionary, earthy beds, but sometimes in thin beds of pure hard limestone. There are also occasionally beds of hard coarse grits or fine sandstones, of similar dull colours with the clays. Among the upper beds of the sub-group thicker runs of sandstone become frequent, having a prevailing purplish tint, and with them occur strong beds of lumpy, gritty clays, of a bright and deep red. The mineral characters of the bottom beds become soon completely lost; the upper limit of this sub-group being thus transitional* and arbitrary. I have usually taken it at the limit of fossils, which are frequently very abundant, though ill-preserved, in the Subathu beds, but wanting (as far as my research extended) in those above. These lowest beds are nowhere better exposed than at Subathu, and in the *khuds* (deep valleys) to the south and west.

* It is not intended by the word "transitional" to convey any idea of locality or position but simply a change in lithological character by gradual alteration.

The lithological elements introduced in the top beds of the Subathu rocks increase, till they predominate, to the entire exclusion of any others; they characterize the indefinite middle sub-group, and are typically displayed on Dugshai hill, and on the ridge to the north of it, through which the tunnel for the Tibet road is being carried. The deep red colour of the clays, and the corresponding dark purple of the sandstones of the middle portion of the Subathu group are useful, general characteristics. I used frequently in my note-book to designate the whole group as the "Red Rocks," as contrasting with the paler clays and gray sandstones of the upper groups of the series. As we ascend in the group, the arenaceous element increases to the almost total exclusion of any other. This is well seen in the steep cliffs that form the summit of Kasaoli ridge on the south-west. In these top-beds, both at Kasaoli and elsewhere, I have found some well-preserved impressions of land-plants, —leaves, seeds, and stems of various species. Among rocks so disturbed as these are it is necessarily hazardous to assign thickness; I do not think 3,000 feet is an over-estimate for the whole group. In separate sections each of the sub-groups shows a thickness of at least 1,000 feet. Whatever duration it may be found necessary from fossil or other evidence to give to this group, or if even it should prove desirable palæontologically to separate more positively its upper and lower members, it must, I think, remain as a *well-defined petrographical whole, an uninterrupted period of some order.* Although there is a total and a very marked difference in the composition of the deposits, showing of course an equivalent change in circumstances, yet this change was, or at least may have been, a change, as it were, of natural growth, not involving the interruption of the formative process. The series seems to represent one uninterrupted sequence of formation, the deposits of tranquil and deeper waters being transitionally succeeded by accumulations of sand, in the uppermost of which we find unmistakeable evidence of the immediate proximity of land. The absence of conglomerates or even gravels among

the Kasaoli beds indicates the continuance of peculiarly tranquil conditions, contrasting, as will be seen, with the phenomena of the succeeding groups. There is perhaps now an over-tendency to allow fossil evidence too exclusively to regulate our classification of rock series. Should the fossil evidence here require a great lapse of time, and consequent sub-division of the series, while accepting these additional facts and their consequences, let us not on that account destroy the independent unity of the whole.

Nahun group.

The rest of the Sub-Himalayan rocks might, from some general considerations, be regarded as but one group. Although the accumulated thickness would thus be enormous, there is much greater sameness of composition throughout than I have described in the Subathu group. The structural character and composition of the Sivâlik rocks, already so well marked in the Dugshai and Kasaoli beds, continued without exception through all the succeeding deposits. But we can distinguish at least one interruption to the process of deposition, resulting in well-marked and general unconformity. The groups, thus separated, I will distinguish as the Nahun group, and the Sivâlik group, or as the middle and the upper groups of the Sub-Himalayan series. It will be seen on the map that the junction of the Nahun group with the rocks on the south is very irregular: it is, however, a very decided boundary, and can be followed with the utmost precision through this region of continuous hills between the Kyarda and Pinjor *duns*. In the *duns* this junction is almost always concealed under the talus of the inner slopes. There is no better section of it than at a point three miles south of Nahun, in the valley of the Markunda; plate I. is a view of this junction, taken from the bed of the river, a few yards to the south. We find there regular beds of unconsolidated, brown, earthy conglomerates, and brown clays, dipping steadily at a moderate angle against the crushed, upturned, lower beds of the Nahun group, in which clays of a clear bright red are conspicuous. The

difference of general texture of the two rocks in contact is so slight as to be quite compatible with the supposition that they belong to one and the same conformable group, the top beds being simply let down by a fault against the bottom ones; but this impression is at once contradicted by the fact that all the larger boulders and pebbles in the conglomerates are of the Nahun sandstone. The identification is easy to any one who is familiar with the rocks to the north; although, as a mass, the Nahun rock disintegrates directly into sand, yet strings and lumps of it do become tolerably hardened both by calcareous infiltration, and under certain conditions of exposure. In the abstract published in the "Asiatic Journal" for 1861, I separated these rocks on this ground alone. I have since had the satisfaction of observing, within a mile of the Markunda section, a distinct case of unconformable overlap of these same conglomerates on the Nahun beds.*

Sivâlik group.

Conglomerates, more or less like those on the Markunda, form invariably the top beds of the Sivâlik group, and sometimes to an enormous thickness. They pass down conformably, and with a gradual change, into an untold depth of sandstones and clays, the latter generally being very subordinate. In these lower beds of this group I failed to discover any reliable primary character by which to distinguish them from the beds of the Nahun group. There is perhaps a shade of difference in the degree of induration of the two, but it is too slight and uncertain to be insisted on. The upper conglomerates just mentioned lap over the denuded base of the Nahun group. The distinctness thus established physically between the two groups is borne out in a most important manner by fossil evidence. This central region of our district, already so frequently noticed as peculiar, is the classic ground of the Fauna Sivâlensis, as at present known to us. These giant fossils are found through some

* The nests of lignite, which frequently occur in the massive sandstone beds of the Nahun group, have more than once excited expectations regarding the discovery of coal.

thousands of feet in thickness of the Sivâlik rocks, but my most patient search and inquiry on the spot has hitherto failed to trace one single fossil to the Nahun beds. I give this as my own experience, but the contrary has been so circumstantially stated, and by such high authority, that the fact, as I put it, must be considered open to doubt. A letter of Colonel Cautley's, published in the "Journal of the Asiatic Society, Bengal," for 1834 (Vol. III., p. 527), contains the following passage—"Lieutenant Durand, on a late visit to Nahun, was fortunate enough to meet with the stratum of marl or clay-conglomerate, on the *north face** of the mountain on which the town of Nahun stands; the remains therein discovered, in my opinion, identify it completely with the Sivâlik stratum, the position of both being similar and in juxta-position with the calcareous sandstone; the fossils in the Nahun deposits are exactly of a similar description to those found at the Kalawala Pass,—a pass in the Sivâlik hills east of the Jumna. Lieutenant Durand's discovery is of particular interest, from its having at once established the formation of the Nahun connecting link, as at this point the low line of mountains skirting the Dhera and Kyarda duns impinge upon the Himalayan chain. Since the discovery of these fossils I have visited the spot, and am satisfied with the identity of this formation with that of the Sivâlik." In a letter of Dr. Falconer's (Jour. As. Soc., Ben., Vol. IV., p. 57) a less exact mention is made of the Nahun locality:—"In one of my tours I have had to return through Nahun. I got a hint of where the fossils came from, and on going to the ground I reaped a splendid harvest. This was on the 20th November (1834), a couple of days after Lieutenants Baker and Durand had got their first specimens through their native collectors." The position is not here specified, and I venture to surmise that the last words of Dr. Falconer's remarks,

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* [Italics are mine.]

the allusion to native collectors, may explain the doubt created by the former quotation. I cannot persuade myself that fossils are *abundant* any where on Nahun hill; I could never get a native even to take the trouble to look among the Nahun rocks, but among the lower hills to the south of the town every villager is familiar with the existence of the fossils. I only insist on this point that special attention may be paid to it hereafter. However rare they may be, fossils must exist in this middle group of our series, and it will be most interesting to detect any change of fauna corresponding to the stratigraphical facts which I have indicated, and which must, I conceive, involve a considerable lapse of time. In a letter received from Sir P. Cautley on this subject, dated 26th February 1859, he says:—"There is no doubt whatever of the fact of vertebrate fossils being found on the *Himalayan side* of the Nahun hills." In confirmation of this statement he goes on to describe a remarkable fossiliferous stratum in the Sivâlik hills east of the Jumna, and, returning to the case in point, says:—"The stratum is a very remarkable one, and the fossils are equally remarkable; no mistake can possibly have arisen on the subject: I found, in company with Colonel Durand, the same stratum on the Himalayan side of the town of Nahun." In the face of such a clear statement it may seem obstinacy on my part even to question the fact. The very slight ambiguity left by the use of the word *stratum* only in the last sentence is my last and only hesitation in the matter; if the identification is only a lithological one, it goes for nothing.

Before leaving this subject, I would desire to correct an impression that is likely to be formed of the great abundance of these fossils. A glorious harvest has been gathered. The discoverers and early collectors came upon the untouched accumulations of denudation from time immemorial; fossils no doubt actually littered the ground in many places; but there will probably never again be such a crop. They occur, and are frequent locally, and in places a careful search will

be amply rewarded, but I doubt if any future collector will be able to say with one of the earlier discoverers that he "bagged three hundred specimens in six hours." I had a man out collecting for about three months; he was a native of Nahun, and an old collector of Colonel Cautley's. He did not find half the number that were worth carrying away, though, I believe, he worked honestly. A large number of small fragments might be obtained, but these are useless.

The varying nature and the doubtful base of these upper groups of the series make it difficult to assign even an approximate thickness. It must be enormous in some places. There are local sections of the coarse upper beds alone, showing a clear thickness of at least 10,000 feet.

Such, then, are the groups that will be traced out in the details that are to follow:—

Sub-Himalayan series.

Upper	Sivâlik......	Conglomerates, sandstones, clays.
Middle	Nahun......	Lignite, sandstones, and clays.
Lower	Subathu ...	Kasaoli, gray and purple sandstones. Dugshai, purple sandstones & red clays. Subathu, fine silty clays, with limestone. *(Nummulites.)*

Himalayan series.

1. Unmetamorphic.

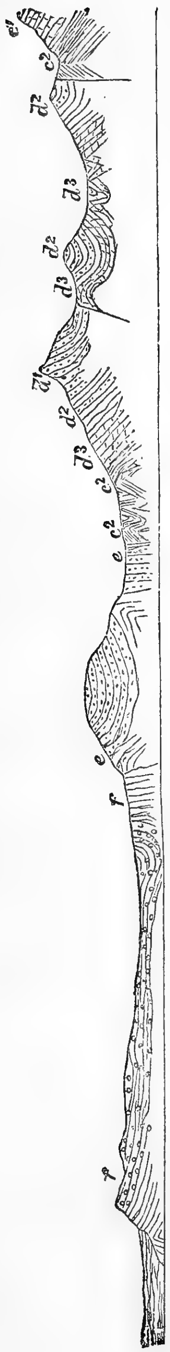
Krol	Krol Hill ...	Limestones.
Infra Krol...	Ditto	Carbonaceous shales or slates.
Blini	Blini river ...	Limestone and conglomerate.
Infra Blini...	Simla	Slates.

2. Metamorphic.

Crystalline and sub-crystalline rocks, &c.

The remarkable similarity of primary characters pervading all these strata, namely, composition, mode of arrangement, and distribution, mark

FIG. 2.



PLAINS. SIVÂLIKS. DUN. NAHUN. KASAOLI. SUBATHU. BOJ.

Diagramatic section of Sub-Himalayan zone. *c.* Krol group. *d.* Subathu group. *e.* Nahun group. *f.* Sivâlik group.

them as having originated from a common set of conditions. The lowest beds, the Subathu nummulitic strata, offer the only, even local, exception to this rule, and they, at least in this district, pass transitionally by alternation into the prevailing type. The arenaceous type is a sharp, fine-grained granitic sandstone, more or less felspathic, micaceous, or earthy, and showing corresponding shades of light greenish or bluish gray, brown, and purple. The argillaceous type is lumpy clay, gritty, micaceous, yellow, brown, and red. The massiveness of the bedding is remarkable throughout. The calcareous element is very subordinate, and only occurs as an occasional ingredient of the other rocks. Its most concentrated state is in irregular nodules in the clays, somewhat similar to the *kunkur* of the present plains' deposits. The diagram section (Fig. 2) will illustrate the general relations of these several groups. I would direct particular attention to the fact, that I base the connection of the several groups of the Sub-Himalayan rocks into one series on purely lithological and structural considerations. Geologists are aware that the precise age of either the Subathu beds at the base, or of the Sivâlik beds at the top of this series is still undefined. And much less are we in a position to discuss satisfactorily the general affinities of

the local fauna and flora which existed throughout the period including these two formations. At the same time, knowing how intimate is the relation between the amount of change in organic and inorganic nature, I would venture to anticipate that, when fully investigated, the successive phases of life in this region, during the entire and prolonged period represented by the great Sub-Himalayan series, will be found to exhibit an intimate interdependence, corresponding to that which I shall show must have existed in the successive conditions of rock formation during the same period.

Relations of past and present conditions.

A most interesting subject of consideration in connection with the Sivâlik rocks is their relation to the great undisturbed deposits of the Indo-Gangetic plains. Save for the one feature of being in their original position of deposition, the Ganges valley deposits have as close an affinity to the Sivâlik group as this has to the Nahun group, and might take rank as a fourth and uppermost member of the series. The comparison is most useful, as helping us to attach a proper value to the relations between the older groups. The upper beds of the Sivâliks, as for instance in the range between the Pinjor *dun* and the plains, are identical in composition and mode of bedding with the deposits of the plains. There is further scarcely a shade of difference in their degree of induration. These deposits overlap the denuded base of the Sivâlik hills, just as the Sivâlik rocks overlap the denuded base of the Nahun hills. The actual relation of the newer strata to those of the Sivâlik hills is precisely what I conceive that of the Sivâlik deposits to have been to similar hills of the Nahun rocks, before they were crushed against each other by some slow irresistible lateral force. The infinitely graduated transition between past and present conditions, as suggested by these facts, has been very forcibly brought to my mind during the study of these rocks, and, from the least expected quarter, namely, that of disturbing causes. A most marked coincidence is observable between the variations of the Sivâlik

deposits and the actual positions of the great river courses: both in quality and quantity the immense accumulations of boulder conglomerates, forming the top of the Sivâlik group, correspond with the actual debouchures of the great rivers from the main mountain mass, thus proving the great antiquity of even the details of the actual configuration. This is indeed a view to which one is predisposed by the contemplation of the prodigious results of atmospheric denudation in excavating the deep winding valleys through the mountains; but as this process has been variously impugned on the score of inadequacy, it is satisfactory to have the stores of geological time thus clearly opened to us. This same point has even a more important application than that just indicated. These immense accumulations of coarse detritus have undergone very great disturbance: they are often deeply faulted, sharply folded, vertical, and even inverted; yet all this has been effected without sensibly affecting the details of contour in the adjoining mountain region. The bearing of observation in this direction upon the theories of mountain formation, and upon theories of disturbance in general, cannot fail to be very important. The most interesting example that I can mention of the fact here brought to notice is the case of the Sutlej at Bubhor, because at this place this mighty torrent has already for many miles flowed through rocks of Sub-Himalayan formations. Just north of Bubhor the river cuts through a ridge of massive boulder beds standing nearly vertical. The materials of this deposit are precisely such as we now find in the bed of the river immediately above. Within a few miles on either side the low ridge formed by these rocks gradually disappears, the rock itself having passed into a pebbly sandstone.

I regret that I shall have but little to say in connection with more recent surface phenomena. As one of the most interesting observations of this kind I may here mention the occurrence of what I believe to be glacial deposits in the Kangra Valley, along the flanks of the Dhaoladhar, at a present elevation of not more than 3,000 feet.

CHAPTER II.—*The Himalayan Series.*

BEFORE describing the Sub-Himalayan series, it will be desirable to give some account of the rocks upon which it rests, or with which it comes in contact. Although my examination of these older formations has not been detailed or consecutive, I can point out some structural features of great interest, which will, I hope, serve as useful indications to future observers.

Lithology.

The almost total absence of fossils in all the rocks of the Lower Himalaya augments indefinitely the difficulty of discovering their relations. In attempting to arrive at a preliminary idea of what, or how many formations may be present, one is left entirely to the unsatisfactory resources of lithological characters. From this point of view I can at present point out but two great divisions of the stratified rocks,—the metamorphic, and the unmetamorphic. Among the latter the dominant type of rock is a gritty slate, sharply thin-bedded, often finely laminated. With these there occur several continuous bands of limestone, some very massive. Sandstones are subordinate, and capriciously distributed. Among the metamorphic rocks siliceous and micaceous schists prevail; hornblendic varieties are subordinate. Through these schists there occur frequently bands of gneiss, which often assumes a granitoid aspect. The only rock of undoubtedly intrusive origin to be found in this whole region of the Himalaya is a trap, which is frequently very extensively associated with the slates and schists; it shows very little variation of type, being, as a rule, basic, only occasionally appearing as a clear diorite; its texture is generally obscurely crystalline, compact, schistose, or even vesicular.

Rock-terms used.

Before going any farther, I must anticipate any ambiguity that might arise from the uncertain meaning of some common rock names. The word "slate" is far too familiar and appropriate to be limited only to rocks exhibiting in some perfection the special phenomenon of cleavage. It is now often defined in this sense, but such is not its general use among English writers. Such a restricted definition would be an awkward impediment in describing these hills where cleaved rocks are not common, though there is abundance of indurated argillaceous rocks to which the words

Slate and grit.

slate and *slaty* in their common acceptation are peculiarly applicable. As a correlative word to slate, I use the word 'grit' to indicate a large intermediate class of rocks, too fine grained and earthy to be called sandstone, and too rough for a slate. Of all sedimentary materials in their unaltered state it is only the very fine silts that become indurated into slates; most clays, earths, and muds would by induration result in *grits.* In adopting this meaning for the word grit, I am again accepting the *practice* of English field geologists, so far as my experience goes. The usual glossary-meaning of the word is a sharp sandstone, coarse or fine; but for the purposes of descriptive geology this definition is almost useless. There is even a direct objection to such an application of the term; why remove a simple *variety,* as sufficiently indicated by the term 'sharp,' from under the generic name *sandstone?* We cannot do without a class name for the rocks I designate grits. I only apply the word

Schist.

'schist' to foliated rocks,—rocks in which sub-crystalline metamorphism is distinctly seen. Of course the varieties produced by gradations are endless; but I wish to convey the idea that these terms are only used to designate each a *class* of rocks. In using compound names to express intermediate varieties, the noun, or the last word of a compound name is that whose characters preponderate; as *e. g.* quartzite-sandstone, to

designate a sandstone in which the granular character is considerably obliterated.

Relative position of rocks.

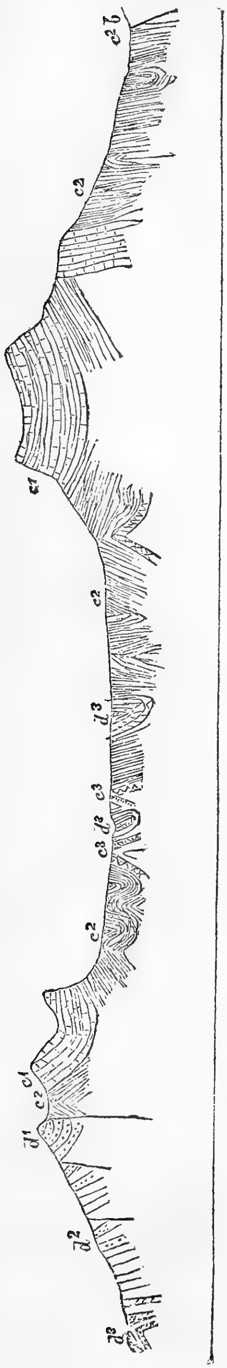
Although I can bring some strong evidence to show that members of the series spoken of as unmetamorphic appear sometimes as schists, and that therefore the separation of the two series, solely on the basis of alteration, is not strictly geological, on the whole, the distinction will, I think, be found to be permanent, and more than simply lithological. The fact that the two classes of rocks are found in close juxtaposition admits of our giving some weight to the generally received opinion, that the least altered is, in the normal order, the uppermost, and therefore younger. Their relative position in the range bears out this conjecture; the slaty rocks form, without exception, a fringe to the greater area of the metamorphic rocks, and in several places projections from this fringe are deeply inserted into that area. In such positions, however, as well as in the fringing band, the apparent relation of the less altered rock is that of *underlying* the more altered. I will describe the detailed relations of these two series in several detached sections or areas, generally chosen with reference to the semi-isolated patches or projections of the supposed upper or younger series.

By far the best sections that I have seen of the upper or unaltered series are in the neighbourhood of Solun, where there is a traveller's bungalow on the new road, midway between Kalka and Simla. This bungalow stands on the low watershed which joins two remarkable hills, the Krol and the Boj; on the south-east, the hill of Kanoge, of similar features to the other two, joins the watershed as about its middle point. To the north-west lies the open valley of the Blini. Along this watershed there is an excellent section, well exposed in the small road-cuttings, in which thin-bedded grits and slates alone are to be seen. The crumpling exhibited by these rocks is excessive, but towards either end the dip becomes more steady, and inclines into the base of the mountain. Fig. 3 represents the section through the Krol and the Boj, taken a short distance to the west of Solun. There are on the line of section two outliers of the Subathu group, which do not extend so far as the watershed; at present, however, we are only concerned with the older rocks.

Section of the Krol and Boj.

Immediately overlying the shaly slates there is found at all points round the base of these hills a coarse, quartzose sandstone; it has here a pale yellow colour, owing to a very small intermixture of fine ochreous clay. In many spots along the road-side it is seen decomposing

FIG. 3.



BOJ. BLINI. KROL. KUNDAH GHAT.

Section of the Krol and Boj mountains. c^1. Krol group. c^2. Infra-Krol group. c^3. Blini group. d^1. Kasaoli beds. d^2. Dugshai beds. d^3. Subathu beds (nummulitic).

into a sharp, coarse, dusty sand, which is carried in quantities to the neighbouring stations as an ingredient for mortar. Although very regular in its position, this sandstone varies considerably in thickness within short distances. It is important to have unmistakeable evidence of this fact, such as we find in the continuous sections round the bases of these hills, because we shall have to apply it freely in attempting to connect these beds with others at a distance. Along the south-east side of the Boj there are not more than fifteen or twenty feet in thickness of this sandstone ; moreover it is here thin bedded, like the gritty slates below it, and like the limestone over it ; its characters are, however, well preserved. Round the south and south-east of the Krol there does not seem to be much more of it than just noticed on the Boj, but on the west and north of the Krol it must be at least one hundred feet thick, and is in massive beds.

The lower limestone and shales.

Everywhere on these hills the coarse sandstone is overlaid by limestone. This too is subject to very decided changes in thickness and in character. The most conspicuous section of it is at the south-east angle of the Boj. There we have at least three or four hundred feet of clear, blue, compact limestone, in very regular, thin, three to six inch, beds ; it here and there contains some well-formed nodules, and regular strings of chert ; while elsewhere, as prominently along the eastern side of the Krol, there seems to be no more than a very few feet of the pure hard limestone, it being to a great extent replaced by thick and thin beds of a very fine semi-indurated marl, or calcareous silt, that breaks up into acicular splinters. In some of the beds of the Boj section an approach to this variety is easily detected. Among all these beds, as we ascend, shaly clays are introduced, often having a light, but bright, pink, and sometimes a mottled green colour. These clay rocks occasionally give rise to a little confusion when they occur at the contact with the Subathu group. The average thickness of all these argillo-calcareous beds must be from five to eight hundred feet.

Upper limestone.

The highest beds of the Krol section consist of strong-bedded, dense, blue limestone, often closely sub-crystalline. This rock is frequently, and also largely, impregnated with chert in a strangely irregular, angular manner, both in continuous strings, and in distinct, angular pieces ; these latter are sometimes very small, and give to the rock a pseudo-fossiliferous aspect. I have failed to observe any marked boundary between these limestones and the beds below them. On the contrary, there seems rather a transition ; there are, not unfrequently, partings of pink and blue shale between the thick beds of hard limestone. There cannot be less than six or eight hundred feet of these rocks, forming the highest member of the Krol section.

Limestone ridges.

The group of strata noticed in the last paragraphs is of great importance in the description of the Lower Himalaya. There can be very little doubt that these limestones are identical with that which most persistently occurs along the crest of the outer ridges from the Krol to Masuri and Naini Tal, and to which the greater elevation and the more rugged character of this belt is due. I believe too that many of the ridges and patches of limestone to be met with in the interior of the same mountain region will also be identified with these Krol rocks. Contorted and broken as these rocks are on the Krol and Boj mountains (and I have only attempted to represent in the section the main features of these contortions), this is by far the least disturbed section of them that I have seen, and the only one that leaves their true position with respect to the gritty slate unequivocal.

Krol group.

Both on the Krol and the Boj these strong, hard rocks are completely insulated upon a base of the thin-bedded, underlying rocks. Denudation is of course the immediate cause of this insulation, but a deeper denudation elsewhere does not insulate them in this manner. These calcareous Krol rocks may, for convenience, be spoken of as one group. The coarse quartzite sandstone I will also speak of as the Krol sandstone. The rather abrupt change in the nature of the deposits indicates a considerable change of conditions, but I think, we may assert there is here no very great, if any, discordance between the Krol group and the underlying series.

The evidence of this section is, I think, conclusive as to the normal position of the Krol group of strata, and warrants the supposition that the actual order of superposition is the original one. The Krol group, therefore, at least provisionally, is to be considered as the most recent formation of all the series of strata of the lower rocks described in the present chapter, the next youngest rocks being the nummulitic beds of Subathu; but a possible modification of this view will be suggested farther on. In attempting to sketch the portion of the section that has been denuded from over the present valley of the Blini, the first idea suggested is to suppose it a great anticlinal bend. But such could scarcely have been the case; the hill of Kanoge, as I have already pointed out, is at a short distance off in a position corresponding to about the centre of this Blini valley, and on it we find the limestone at the same height as on the Krol and the Boj, and forming again a broken synclinal.

Degree of induration.

It may be noticed that the terms I have applied in describing the rocks of this group indicate a degree of induration inferior to that of the underlying strata. The term slaty is here scarcely applicable. It may be doubtful how far this difference in induration is due to the more purely argillaceous composition of the earthy beds of this upper group, or to their greater thickness of bedding, or to their being intercalated among hard limestones, where all have apparently undergone the same amount of disturbance. It is a fact, however, not to be lost sight of. Elsewhere, beds that I identify with those of the middle Krol are considerably more hardened, there being also in such cases independent evidence of the rocks having undergone greater compression.

In the mode of disturbance of the strata these two remarkable mountains exhibit, typically, a feature that is not so strongly marked elsewhere, if indeed it be not peculiar to this portion of these hills. It is a very common fact throughout the external zones of the Lower

Himalayas, as in other mountain regions, that the ridges occur along synclinal axes in the strata. This character is even more markedly exhibited in the Subathu group than among the Krol rocks. In the Krol and the Boj we find this structure exaggerated into a quaquaversal convergence of dips. It is best exemplified in the Boj. The main road passes round the sharp south-east end of this elongated hill, and on all three sides the rocks are seen to have a steady and high dip inwards. At the summit this arrangement produces the strangest appearance, though it is only what might be expected with such a peculiarity of dip. There is a narrow rim of limestone surrounding a deep hollow, which in form perfectly resembles a crater. The bottom of this hollow cannot be much less than one thousand feet from the rim, and there is but one exit, by a narrow slit on the north-west side, through which a small stream of water passes to the Blini. There are three such craters, or cups, in a distance of four miles and a half, which is about the length of the Boj ridge. It were impossible to account for such a structure as this by any single operation of disturbance, but it would readily result from flexures corresponding with the actual run of the ridge, if the strata had been previously broken into moderate anticlinal and synclinal folds in a transverse direction. The coincidence of two synclinals crossing each other nearly at right angles might evidently produce, by the aid of denudation, these crater-like hollows.

Ridges on synclinals.

Crater-like hills.

From the section before us it would seem easy to determine what the rocks are which underlie the Krol group. Along the road, on the south side of the Krol, there are numerous clear cuttings, showing the Krol limestone and sandstone most regularly and conformably overlying black, carbonaceous, shaly slates. In following the section downwards into the valley towards Kanoge hill, the same description of rock appears throughout. On the Boj we find a precisely similar section: along the stream which flows from its inner

Underlying black slates.

basin to the Blini, the slates are throughout more or less carbonaceous, yet on the road which winds along the low watershed connecting the two hills, over rocks, all of which, so far as I can make out, must be the actual continuation of some of those noted in the above sections, this carbonaceous character totally disappears. The beds in the valley on either side must be at least as low in the series as those on the watershed, which are at an elevation of some 3 or 400 feet higher on the same strike. At many points on the watershed the rocks have been cut into for the road-way to a depth of ten or fifteen feet, but without showing any difference. Excepting in this one respect of colour, and the very small amount of carbon that produces it, the beds of the watershed are readily identifiable with the dark-coloured, carbonaceous rocks to which we have just alluded. Similar cases on a smaller scale may be noticed on individual spurs. In many instances a transition is traceable by the gradual disappearance of this black or colouring ingredient. Frequently too, in such positions a calcined appearance is very marked, as if the carbon had been abstracted by some rapid process of combustion. This calcined appearance is often seen at a distance from the immediate proximity of any black rocks, but, as a rule, there is not even this slight evidence (if it can be considered any) of the carbonaceous character having formerly existed in beds which I am inclined to suppose once possessed it.

Carbonaceous element.

Although I have not succeeded in finding a single vegetable impression in these black rocks, I can hardly think that the carbonaceous ingredient can be other than cotemporaneous; for we find it characteristically displayed over so large an area, at such great distances (as will be frequently noticed in the following pages), always in beds of the same stamp, and which are thus mutually identifiable, as well as by analogy of position, and by more or less continuous connection. The further inference becomes then very strong that an element so widely spread at the time of original deposition could not have been very locally absent, as has just been described in the

beds of the Solun watershed, and elsewhere. We are thus compelled to admit its local *removal* in such cases. Weathering is almost the only cause I can suggest, though it seems inadequate to account for all the facts.

In faults.

The most concentrated form in which this carbonaceous matter occurs is as a fault-rock, or where great crushing has taken place.* In such positions it is of very common, almost general, occurrence throughout the Lower Himalaya, being found in fault ground among schist-rocks even far away in the interior. The fact of the very general occurrence of this carbonaceous matter in this position, in fissures and in lines of crushed rock, in greater proportion than anywhere else, and also in places far removed from where there is any appearance of the black slates, may, with reason, be thought to invalidate the opinion I have expressed as to its origin in those slates; it certainly leaves that opinion conjectural. That the two phenomena are connected seems probable.

Infra-Krol beds.

The Infra-Krol beds consist of an uncertain, but considerable, thickness of thin-bedded gritty slates, normally carbonaceous. Among these there occurs occasionally a thicker bed of fine sandstone, generally brown and iron-stained. There are also, but more rarely, lenticular layers of limestone. Just at the rise to the Boj, from the Solun watershed, there is an instance of the latter kind that has puzzled me a good deal ; if original in the slates it must be very discontinuous, as it does not show again in many good sections

* Some little interest was excited about a year ago in these provinces about a rock of this kind in the neighbourhood of Subathu. Some discoverers, more ardent than wise, insisted that it was coal. There is some excuse for such a mistake being made from a superficial inspection of the matter itself. It has a brilliant jet-black colour, and is even slightly bituminous. Some of this supposed coal, of which I made a rough assay, gave as much as twenty-five per cent. of fixed carbon, ten per cent. of volatile matter, with sixty-five per cent. of ash. The greater portion of the ten per cent. driven off as volatile consisted of sulphurous fumes, a small proportion being combustible hydro-carbons. The ash is impalpable earth. Besides, even in hand specimens, this pseudo-coal always betrays its condition, being a flaky mass, breaking up into scales, like micaceous iron-ore, which it sometimes almost rivals in brilliancy.

close by ; there is, moreover, the possibility in this spot of its being a remnant of the nummulitic rocks caught in a contortion of the slates ; but I could not discover any organic forms in it. The beds to which I will apply the term Infra-Krol group may be from 1,000 to 2,000 feet in thickness.

The description I have given of the Infra-Krol beds would answer generally for the entire series of the unmetamorphic rocks below the Krol group. Although the base to this series of strata is not discoverable in this region, we find in them here a well defined horizon, a band of rocks that is very peculiar and characteristic, and which can be traced without any doubt to great distances,—a remarkable circumstance when we consider that their united thickness is usually inconsiderable. This band promises to be of special utility in identifying the rocks in the interior with those of the outer parts of the Lower Himalayan region. The principal rock of this little group is a pure limestone, very dense, sometimes compact, sometimes sub-crystalline; its commonest colour is pale pink, but often blue and greenish yellow; it occurs in thin, well-defined layers, but these are often agglomerated together into one mass, the beds showing only as bands in this mass. From fifteen to twenty feet is the pretty constant thickness of the whole. The limestone by itself would be far from a satisfactory guide in the identification of disturbed strata, where it is sometimes brought into proximity with other similar rocks, such as those of the lower Krol beds, with which it might readily be confounded. It has, however, a constant companion more peculiar than itself, and the two combined furnish an unmistakeable clue. This other rock is a kind of conglomerate. It occurs, I believe, below the limestone, though in the many inverted contortions it often appears above. The base of this conglomerate is a fine, gritty slate, of a dull green, or blue colour, in fact altogether like the thin-bedded rocks in the midst of which it occurs. Through

Blini group.

Limestone.

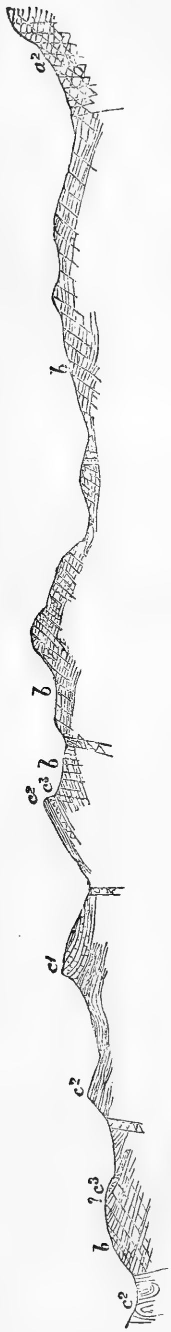
Conglomerate.

this base well-rounded pebbles of quartz are thinly scattered, seldom larger than a hen's egg. These pebbles are sometimes so scarce as easily to pass unnoticed without special search. In most places sub-angular fragments of a *slate* rock are the prevailing foreign elements in the conglomerate, which thus assumes a very brecciated aspect. The whole appearance of this rock is often that of a trapash. It is frequently thick-bedded, sometimes massive; its total thickness varies from ten feet to one hundred, or more in some obscure sections. I have traced it from the Blini to Naini Tal. I will call this conglomerate and its attendant limestone by the name of the Blini group. From the source of the Blini river to its confluence with the Ghumber these rocks are never far off, and in many places they crop out across or along the river. As an irregular accompaniment of these Blini beds I must mention a clear coarse quartzite: at two or three points in the lower course of the Blini this bed shows apparently over the limestone. It may elsewhere assume a greater development.

The bend that the Blini river takes, from the longitudinal band of soft nummulitic rocks, through which it flows at first, across the general strike of hard rocks, under the north-west base of the Krol, enables us to see most unequivocal evidence of the true position of these Blini beds as regards the Krol group. In the valley west of Solun the Blini limestone shows at several places at and near the boundary of the soft nummulitic rocks. In the transverse gorge of the Blini stream the same beds are several times exposed crossing the stream; and again, along the lower valley of the same stream to its confluence with the Ghumber, the course of the Blini beds is about coincident with that of the river. The Blini group seems to be underlaid by the same kind of rocks as those overlying it. In every section that I have seen (and they are very numerous), exactly the same description of thin, shaly slates, and grits,

Section in Blini river.

FIG. 4.



BLINI. KEARI. SHAKU. TARA DEVI. JAKO. MAHASU. MUTTIANI. HATU.

Section approximately along the Simla watershed-ridge.

*a*². Crystalline schist. *b*. Slates (the cross lines are only conventional). *c*¹. Krol group. *c*². Infra-Krol group. *c*³. Blini group.

with or without the carbonaceous element, are found on both sides; and it is impossible to suppose in every case that we see only a faulted, or contorted repetition of the overlying strata.

Section from Simla.

The section along the watershed ridge upon which Simla stands, and in continuation of that of the Krol, is one of the most characteristic that I can give. The actual straight line of such a section (Fig. 4) may be taken on the north-west of the Krol, from a point north-east of Subathu to Hatu, a summit 10,469 feet in height, rising on the east of Narkunda and Kotgurh. The direction is about north-east-by-east, and the distance thirty-two miles. The low ridge at the south-west end of the section is nearly in the strike of the Krol; it is formed by a rise of the Blini limestone. The valley on the north-east is the lower reach of the Blini, and corresponds with Kundah gap on the north-east side of the Krol. It will be simpler to omit the description of that portion of the section immediately to the north of the Blini, until after I have noticed the rocks at Simla, where, I believe, some of the beds already described can be identified.

Blini rocks at Simla.

Under that portion of the Simla ridge known as Boileaugunge, on one of the northern spurs, about 600 feet below the house called the Yarrows, we find a limestone and a grit conglomerate answering exactly to the description I have given of the Blini rocks, and which I cannot hesitate to identify with that group. At the place indicated these beds have a moderate dip to the south-south-west, which is the general dip all along the ridge at Simla. On the south-south-east spur from Jako, known as Chota Simla, at a small distance below the ridge on the north-east side, the same beds crop out. I noted both these localities in going to visit the slate quarries.

Simla slates.

The material used so generally at Simla as roofing slate is an imperfect lamination-slate, or indurated shale, obtained always from below the Blini beds; it is a finer variety of a great series of shaly slates, grits, and thin, fine, earthy sandstones, that are well seen in the downward continuation of these local sections at Simla, steadily underlying the supposed Blini beds. The strata being far less disturbed here than along the outer zone, these slates must, I think, be taken as the undoubted basis of the Blini beds; they are in every way similar to those often seen with the Blini rocks about the Krol. These Simla slates are quite free from carbonaceous colouration, and it may be that this character is peculiar to the otherwise similar beds which intervene between the Blini and the Krol groups, and which I have designated the Infra-Krol band. If this inference be correct, this carbonaceous character would occasionally be a useful means in helping to distinguish between groups of strata that are in other respects very similar.

Simla ridge.

Any geologist who had only studied the Simla rocks as seen on the top of the ridge, along the roads and paths about the station, would be surprised to be told that these upper strata were underlaid, right through the hill, by

such beds as I have just described. These upper rocks are what would be called "metamorphic"; they are highly foliated schists; in parts, as on Jako, mica schists predominate; elsewhere, as on Boileaugunge, they are siliceous. They are sometimes even hornblendic and garnetiferous, as on the top of Jako, and on the point just west of Boileaugunge. Besides being in a more highly mineralized condition, all these beds show much more *local* crushing and contortion than do the underlying slates, and, as a consequence, they are very frequently traversed by large seams and veins of quartz, which greatly add to the general metamorphic aspect. Quartz veins are rare in the slates unless very locally along lines of strain.

Upper rocks most altered.

If then these strata be in their normal relative positions, and if the identification of the limestone, &c., below the ridge, with the true Blini limestone be correct, we must seek in the Simla beds for the representatives of rocks that overlie the Blini group in the Krol section. This can be done without any great strain on the facts. The schists of Jako must, in this case, be the representatives of the shaly slates of Solun,—the black shales at the base of the Krol. At a few spots, as along the Tibet road near the bazaar, on the north side of Jako, we find some direct confirmation of this supposition in the decided traces of a carbonaceous element in the schistose rocks. In the same view the schistose quartzites of Boileaugunge, which in strike would come over the Jako beds, and which extend down to the toll-bar, at the gap to Tara Devi, would represent the Krol sandstones, only considerably increased in thickness. At this gap there is a synclinal axis with much of the black crush-rock about it; it runs north 40° west, through Jatog hill. On Tara Devi we have the reverse of the synclinal, and the repetition of the Simla section, the highly garnetiferous schists, and the schistose quartzites, all having a moderate dip to the north-north-east. The high cliffs on the west face of this hill are of these latter rocks. Even within so short a distance the thickness of the quartzites is less than on

Representatives of Krol rocks at Simla.

the spur to the north of the synclinal,—a fact that increases the probability of their being the representatives of the Krol sandstones. In these schistose quartzites is found, very well developed, a structure that has, I think, been described by the name *bacillary*, consisting of very straight ribs and grooves, both being scored with minor ribs and grooves. This structure occurs in the plane of the bedding of the rock, and generally transverse to the present dip; but I failed to trace any constant relation between the two.

Bacillary structure.

I have yet to mention the highest rocks that occur about Simla. To the west of the toll-bar gap there must be a fault along the synclinal axis, with a considerable downthrow to the south-west, and accompanied by a general subsidence of the rocks to the north-west of Tara Devi. This line of fracture passes through a portion of the Simla ridge at Jatog, and we find there a considerable thickness of the strata that overlie the quartzites. The section is best seen on the south-westerly spur from Jatog hill. The quartzites occupy the lower extension of the spur, corresponding to the Sairi ridge at Jatea Devi, and they have the same low dip to north-north-east; over them on the ascent there is a considerable thickness of dark blue limestone, schistose and carbonaceous, or perhaps more accurately, graphitic. Above these there come more schists, highly altered, almost gneissose, and then again strong-bedded, hard, blue limestone, with much irregular chert. Over this there are some garnetiferous mica-schists, but being at the summit, and in the very line of disturbance, their position may be doubtful. On the whole, these uppermost beds of the Jatog section correspond well with those which we have already noticed in attempting to identify the whole series of these rocks about Simla with those of the Krol section. I believe we have here the Krol group in a more altered state.

Fault south of Jatog.

All these Simla rocks, from the Blini group up, present the same difficulty,—that of their highly metamorphic condition as compared with

the beds underlying them. To account for a state of things so apparently anomalous and incompatible with the generally received notions of metamorphic action, one is at first tempted to look for grand inversions of the strata. I do not think, however, that the general section gives any encouragement to this mode of explanation. The very approximate correspondence in the sequence of the deposits in the two sections, at Simla and the Krol, confirms the negative evidence against the inversion of the Simla rocks; the theoretical puzzle of the metamorphism of the upper part of the series must therefore be got over in some other way. We may thus consider the more complex composition of the upper deposits to be an inducing cause of change, while their more heterogeneous conditions of texture as a series would account for their greater local contortion and fracture; and this state would itself be an inducing cause of mineral modification, and especially of the introduction of vein quartz.

Section south of Tara Devi.

The portion of our general section intervening between the rocks I have described about Simla, and about the Krol, is not so well understood. Along the two roads to Simla we get excellent sections of these beds. On the new road, the more easterly one, we have seen the schistose quartzite dipping to north-north-east, and forming the south-westerly cliffs of Tara Devi. On the lower road the same beds, with a smaller inclination in the same direction, extend along the low ridge for the greater part of the way to Sairi. The nearest rocks to the south of these, and of which we have already spoken, are the Blini limestone and conglomerate, as they appear at the turn of the Blini, on the north-west of the Krol. These beds can be traced for some way from this place on the north side of the stream that flows from Kundah Ghât (the gap to the north of the Krol, between it and Hirti Hill), along the base of the spurs south of Keari bungalow. In a north-westerly direction these Blini beds stretch up from the river along the south-westerly spurs of the Sairi hills; they are crossed several times along the road between Haripur and the crest of the hill, being greatly contorted. Thus there remain about six miles in a *direct line* along the eastern road, and about four miles along the western road, still unaccounted for. On both lines there is scarcely an exception to the north-easterly dip of the strata, these exceptions being narrow bands of crushed rock, indicating probably lines of twisting and displacement, or even of considerable faulting. About thirteen miles from Simla, a short way to the north of Keari bungalow, there is a rock that may help us to unravel the section; it is a hard blue limestone, thin-bedded, about twenty feet in all, dipping at a high angle to the north-east. I suppose it to be the Blini limestone. In the unimportant character of being uniformly of a blue colour, it is less like the Blini rock than what we find at

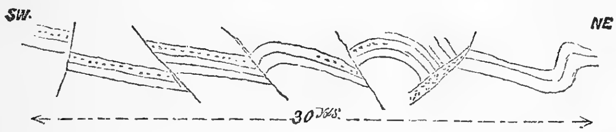
Keari limestone.

Simla. Under it, along the road to the bungalow, and stretching up to form the crest of Hirti hill, on a spur of which the bungalow is built, there is a rock that may represent the Blini conglomerate, which it resembles in many ways, though here not conglomeritic. It is a greenish slaty grit in massive beds, with occasional thick beds of a harder, sandy variety of a reddish tint. Below these, down the spurs to Kundah Ghât, there is a fine section of beds that one can scarcely hesitate to identify with the Simla slates. Here also, though considerably more disturbed than at Simla, they are quite free from foliation, or from adventitious veining. The position of these slates confirms greatly the opinion that the Keari limestone is the representative of the Blini rock. In proceeding down towards

Kundah Ghât.

Kundah Ghât the dip gradually decreases to a small angle, but the beds are greatly broken up, and traversed by frequent cracks, and small faults. Fig. 5 represents a section of these rocks, only thirty yards in length, on the road side about half way down the hill. Close to the gap (Kundah Ghât) the dip becomes suddenly vertical again, and continues so up to the rise of the Krol. The view

FIG. 5.



Exact section, thirty yards long, showing mode of fracture and contortion of the slates, north of Kundah Ghât.

I take of the section here is represented in the section (Fig. 4), showing a considerable fault along a folded anticlinal flexure. The small details of structure exhibited in Fig. 5 are certainly in keeping with this general view. If my identifications of the rocks be correct, this fault must have a total throw of several thousand feet. It is along this line that the Giri flows in such a remarkably straight course to the south-east; and we will presently see how similar the section remains in that direction.

The description of the section to the north of the Keari limestone, or perhaps we may say of the Blini limestone at Keari, is not easy. This portion of the watershed-ridge consists of

Shaku gap.

a series of gaps and low eminences connecting Hirti and Tara Devi hills, being across the strike, as is usual in these purely denudation-ridges. The rocks are well exposed along the road cuttings. Above the limestone there is a thick band of mica-schist much traversed by quartz; it is altogether very like the rock of Jako. It is succeeded in ascending order by very finely bedded, slaty schists, and sub-schistose flags, dipping at high angles, more than 50°, to north-north-east. There is thus altogether a greater apparent thickness of rock than we have as yet supposed to intervene between the Blini limestone and the Krol sandstone. The section is not, however, unbroken; a more careful search might find, above the strong siliceous beds that form the low peak over Shaku gap on the north, evidence of a repetition of Blini limestone; immediately on the north of the knoll formed by these beds there occur again softish micaceous schists, that pass, with a low undulating and contorted dip, under the quartzites of Tara Devi, as the schists of Jako pass below those on the north of the synclinal. At Shaku gap and along the short incline down to the next gap, we are, moreover, at liberty to suppose any

amount of displacement, the rocks being vertical, and with, as usual in such places, much of the black crush-rock. By some such supposition the whole section between Simla and the Krol is closed up.

Near Sairi bungalow.

Along the old road, from Haripur to about two miles north of Sairi bungalow, the same succession of rocks can be recognised as between Kundah Ghât and Tara Devi. On the north-east side of Sairi hill there is a small thickness of blue limestone like that of Keari, and in an analogous position, but here the rock underlying it is abundantly conglomeritic. Here also this limestone is the line of demarcation between overlying beds of very decided schistose character, and the underlying slaty rocks,—a position already noticed, as so marked in the case of the Blini limestone at Simla. The Shaku line of strain, with graphitic crush-rock, passes along the steep face of the hill north of Sairi bungalow.

Section N. E. of Simla.

The ridge of Mahasu, to the north-east of Simla, is the best defined longitudinal portion that occurs along this composite watershed. In Mahasu ridge we have the reverse of the Simla dip ; the anticlinal axis being, as usual, a line of greater denudation. This anticlinal is not a single well defined bend. Going along the connecting ridge, from the north-east point of Jako, we find the Simla slates for about a mile approximately horizontal, as seen in the tunnel through which the road passes. Immediately beyond this a high south-south-east dip appears again, and after a short distance we come upon a line of intense strain and contortion, horizontal and vertical strata being seen abutting against each other repeatedly. Still in all this confusion I could detect but the repetition of the thin-bedded grits and slates of the Infra-Blini series ; the faulting, if any, must be slight.

Change of dip.

The introduction of a prevailing north-north-east dip towards Mahasu is very gradual. Along the rise to the ridge, and on it, the inclination of the strata is low and irregular. On the new road, which winds at a constant level along the north flank of the ridge, the same slaty rocks are seen in this condition of broken horizontality ; sharp rolls or contortions are not unfrequent, and in no constant direction : the flat undulations also vary, although their longest slope is most frequently to the east-north-east and east. The beds seen on the top of the ridge are more schistose than those below. It is possible that the Blini group is somewhere to be seen, but I failed to notice it.

Fagu to Muttiani.

Shali.

From Fagu bungalow, at the east end of Mahasu ridge, passing Theog to Muttiani, there is no remarkable eminence along the winding watershed. At Muttiani this main drainage ridge is connected with the more lofty ridge which extends from the snowy peaks in a west-south-west direction to terminate in the summit of Shali,—a conical peak that forms a well known feature in the landscape from Simla. Between Fagu and Theog there are two or three instances of special strain and local contortion, but, as we have seen between Jako and Mahasu, no new rock is introduced, and at Theog the same thin-bedded slaty grits, which I presume to be the Simla slates are, as usual, irregularly waved horizontally. To the north of Theog hill a more steady dip commences ; its mean direction is east-north-east, but still at a low angle. Some strong quartzose beds here

determine a short ridge along the strike. There is also a general increase of the siliceous element, and the texture exhibits incipient foliation. The portion of the higher chain, between Muttiani and Narkunda, is made up of these schistose slates, and quartzose rocks; some bands are complete mica-schist. At several points the graphitic ingredient is very manifest. The strata have a moderate dip of 20° and under to the north-east and east.

Narkunda and Baghi.

Along the road between Narkunda and Baghi there is no change worthy of notice, save the gradual and complete general development of the foliation. At Baghi the mica-schist still maintains the low easterly dip. The portion of the section last noticed is along the north flank of Hatu. At the summit of this hill, and overlying the rocks of the lower section, we find coarsely porphyritic gneissose schist, in massive beds inclining at 10° east to 30° north.

Simla Section.

The section through Simla, of which I have given an outline, is in several respects remarkable. A very critical point in the interpretation of it is the identification of the Krol group at Simla itself, and the chief evidence for this is the band of strata so like the Blini group, and which I believe to represent that group. But for this identification the close connection of the uppermost beds of the unaltered series with the great mass of these rocks,—the infra Blini beds or Simla slates, would, as far as my observations extend, remain very doubtful; and without this link we should have been still further at a loss for any connection between the Krol rocks and the metamorphic rocks. In this section the connection is less broken than we shall find it elsewhere: at Simla we have the Krol group in an advanced state of metamorphism, and resting on strata which appear gradually to become associated with the highest type of metamorphism, in the porphyritic gneiss of Hatu. What has just been said of the Simla section seems to be

Slight disturbance.

connected with the comparatively little disturbance it exhibits. This character is marked from the very outset. In the region of the Krol we find the uppermost rocks much less confused than at any other place I could point to. The line of the contortion and faulting along the lower Giri and Ushni is much reduced beyond Kundah Ghât; it seems to vanish through the greater general elevation of the rocks to the south-west of it, of which elevation the

removal of the entire Krol group is the most noticeable result. Throughout the rest of the section the same comparatively undisturbed stratification obtains, and this seems to become more marked as we proceed inwards to the higher hills; the gneiss on the summit of Hatu is almost horizontal. There is another peculiarity worthy of notice and suggestive of connection with those already mentioned. Throughout the whole of this section, although it is the portion of the Lower Himalaya region which I have most frequently visited, I have noticed but one instance of intrusive rock; it is a small trap dyke in mica schist, about three miles from Narkunda, towards Muttiani. Within ten miles to the north-west of the Krol, green-stone appears among the uppermost rocks, and rapidly increases in frequency. Similarly to the south-east, about the lower Giri, green-stone is abundant. Again, due north of Simla, in the valley of the Sutlej, where the unaltered Krol and Infra-Krol groups appear deeply set in among the metamorphic rocks, trap rock occurs in great abundance.

Absence of intrusive rocks.

Abundance in Krol rocks elsewhere.

The Simla section serves as a convenient starting point from which to trace the connection of the rocks on either side: I will first take up the region immediately to the south-east. I have already mentioned the Chor mountain as a very remarkable feature. It attains an elevation of 11,982 feet, and is by far the highest point so near to the edge of the Lower Himalayas. It is also in other respects peculiar: it presents on a small scale a complete example of a phenomenon that is more extensively developed elsewhere, and of which a satisfactory interpretation is necessary to the general explanation of the mountain structure; I allude to the strange mode of occurrence of great masses of granitoid gneiss. The *allure* of this rock, as judged from local and limited

Rocks to the south-east of Simla.

Chor mountain.

sections about the Chor, is apparent interstratification; although here too we have undeniable proof that it is abruptly discontinuous in strike. Almost equal anomalies meet any supposition of the rock being intrusive.

My examination of this mountain has been very incomplete. I have however been on all sides of it, in marching from Simla to Masuri by three different routes across its northern and southern flanks, and my observations on these three occasions are sufficient to indicate the general physical features of this hill. The most northerly of these routes is the regular road by Chepal and Deobun, leaving the Chor quite to the south.

Upper valley of Giri river.

Along the valley of the Giri, from Kot to where the river turns at right angles to the eastward, the beds that I have spoken of as the Simla slates or Infra-Blini series are the only rocks seen: this line passes right across the base of the Chor on the north-west, and is parallel to the section which I have described along the Simla watershed. The rocks are in a state of broken horizontality, being occasionally crushed or sharply bent, but on the whole only slightly inclined. In the northern part the tendency of this inclination is most markedly eastwards, and in the southern it is north-north-east; in both instances being more or less in the direction of the Chor. In following up the valley of the Junkunta (the stream flowing northwards from the Chor) this moderate inclination of the strata is preserved, the rocks becoming gradually more schistose; above Mandera there are hornblendic and felspathic schists with intermingled graphitic matter, and these are succeeded by garnetiferous mica-schists, more or less siliceous. Such are the rocks on the spur crossing from Mandera to Suran, and they there have a moderate dip to north-east and east-north-east. At Suran coarsely porphyritic gneiss is exposed in the river-bed, I believe *in situ;* the schists close by are, as elsewhere, only slightly inclined, but here the inclination is outwards,—from the mountain: they thus apparently rest on the granitoid rock. Again, in crossing the eastern spur from Suran to Baluk these same schists occur the whole way, and in the same slightly disturbed position. Massive limestone appears below Baluk. I can only make a faint conjecture as to the identity of the rocks in this section on the north of the Chor with the others I have referred to of similar lithological character in the Simla district. The ridge of Bulsun and Chepal, along which the Masuri road runs, seems to correspond with Mahasu; the siliceous schists and schistose quartzites, having a slight northerly dip, and forming the great precipices on the south face of the ridge, may be the same as the Boileaugunge quartzites (Krol sandstone). If such be the case, we should expect, in going southwards, along the connecting ridge from Chepal to the Chor, to find the Simla slates on the intermediate mountains. In support of this general view we find the Blini limestone and its peculiar conglomerate (or else an exact counterfeit of them) where the road crosses the Tons, about three miles below its confluence with the Pabor; the eastern pier of the swing-bridge rests upon these rocks. This locality is in the line of the general strike on Chepal ridge.

East spur of Chor.

Chepal ridge.

South flank of Chor.

In the section round the southern flanks of the Chor we meet with rocks similar to those on the northern. In the Bajathu, and on the spur to the south of it, the slates are little disturbed. Above Ratub the rocks become schistose, still with a low easterly dip. The siliceous mica-schists continue up to Hanuta;

about Banallah and Sohana soft mica-schists, and hornblendic, garnetiferous schists are horizontal, or incline at a low angle to the east. A dense hornblendic trap-rock occurs among these rocks in this locality ; it is the only rock of its class I have noticed in the vicinity of the Chor. On the spur east of Sohana the felspathic rocks show in massive beds, twenty and forty feet thick, and still dipping at 15° to east-north-east. The same massive granitoid rocks appear in the valley, about a mile above Talichoag ; and again on the spur west of Nara they occur low down. There are here some coarse pegmatitic varieties, with lumps of schorl, as large as a man's head. East of this spur a high northerly dip often occurs locally, both in the schists and the gneiss. At Chara mica schists are again but slightly inclined, and to north-north-east. In the relative positions of the rocks there is however a very important contrast between the junction on the north and on the south of the Chor. On the north the schists rest on the granitoid rock. On the south the superposition of the latter is decided.

Granitoid rock of summit.

I went up the Chor along the spur west of the Palar. The ascent was very laborious, as the snow was in many places waist-deep (23rd February). The sections were of course concealed, but in the great, bare masses on the summit I could see that the rock was the same as elsewhere,—a coarse, but distinctly foliated rock, weathering in a sub-angular manner, corresponding with such a texture, and not as a massive rock. I did not cross the south-eastern spur at a higher point than Geruani, where, as might be anticipated, the felspathic or granitoid rocks are not found. Thus, then, the mass of granitoid gneiss is isolated. Besides the many local observations proving that the foliated structure of this gneiss is constant, and that it always has a stratified appearance in these rocks forming the summit of the Chor, and showing also the general parallelism of dip in these rocks with that of the associated schistose and slaty beds, we find in addition that the *general* feature of interstratification is equally well marked. In the great gorges on the south of the mountain the outcrop of the junction of the granitoid with the schistose rocks forms a decided curve inwards, or to the north ; while at Suran, on the north of the mountain, there is an equally distinct curve in the same direction (outwards), the river at Suran having markedly undercut the plane of junction. In both cases, however, and especially on the south, the underlie of this plane of junction seemed to me steeper than what should be due to the low angle of dip in the associated schists, supposing the two coincident. The form of the mountain also corresponds with the structure I have described, being more steeply scarped on the southern face than on the northern. The ground-plan of the granitoid mass (as broad as long) is nearly as great a difficulty on the supposition of intrusion as on that of mere metamorphism ; and this difficulty is increased by the absence, so far as observed, of any of the concomitants of igneous intrusion, such as dislocation with permeation of veins, or of special contact action of so great a quasi-igneous mass.

No veins.

South-east of Chor.

The region on the south-east of the Chor presents one important point of agreement with the sections on the north-west and on the south-west : the inclination of the strata is towards the mountain. I cannot state the facts so closely as in the other cases, as I have not been on the Haripur ridge, which is the main south-easterly spur of the Chor, but from Geruani and Juin all down the valley of the Neveli to beyond the Tons a north-westerly inclination is general in the strata. The section is, however, much more complicated than on the west : from the Giri up to the

appearance of the crystalline rocks we found on that side an apparently regular succession of rocks answering to the general characters of the Infra-Blini series ; on the east, however, within a few miles of the summit, we find that limestone becomes a prominent rock. Below Baluk, far up one of the gorges of the Suinj, there is a dark, carbonaceous, and schistose limestone, dipping in under the schists of the ridge. It is underlaid by sub-schistose slates, and these by a great thickness of massive, compact, and often cherty, limestone. Locally this rock exhibits much dislocation and twisting, in consequence of which, and of its generally small inclination, it appears low down all along the valley of the Suinj, and in the Tons about its confluence with the Suinj. The same limestone reaches up on the east of the Tons to form the lofty ridge of Deobun. At many places along the Tons and the Suinj the limestone is seen to be underlaid by brown, crumbling, clay slate, and other varieties of similar rocks. It is in these strata that the rich veins of galena occur at Oniar on the Tons, a few miles below the confluence of this river with the Suinj.

Limestone.

Deobun ridge.

An essential point in the discussion of the district of the Chor is that of the identity or the distinctness of the great limestone formations of the Suinj valley and of the Krol. As bearing upon this question, I will indicate the possible continuity of the two rocks. The great spurs which radiate from the Chor are cut off on the south-west and south by the remarkably straight valley of the Giri. On the opposite side of this valley runs the equally straight, longitudinal range of limestone. The synclinal form of the ridge is maintained throughout, though locally the rocks are greatly disturbed. In crossing the ridge from Mypur on the south to the confluence of the Palar and Giri, all the members of the Krol group are easily recognized. At the base, in the Giri, the Blini limestone occurs typically. The great upthrow to the north of the river brings in the same series of grits and slates as described south of Keari ; for some miles up the Palar there is an unbroken section of these slates, showing a varying dip to the north-north-east. The great faulted anticlinal of Kundah Ghât, to which the remarkable features just described are due, after continuing so steadily in a south 40° east direction for about thirty-five miles, down the valley of the Giri to its confluence with the Palar, at this point becomes variously split up ; and the limestone range, which it had so strictly

Suinj and Krol rocks.

Lower valley of Giri.

End of Giri fault.

defined, shares its fate. Some obscurity is thrown upon the nature and extent of this interruption of the fault, by the fact that the cutting off of the Subathu group, to the south-east, coincides exactly with the direction of this fault line. The extinction of the Subathu group can be shown to be due to general easterly elevation and consequent bevelment of its beds, and the coincidence just noticed suggests that the similar upheavals to the north-east of this line are interrupted portions of the same phenomenon. However this may be, we find that from below the confluence of the Palar, the hills on the left of the Giri are composed of the Krol and Infra-Krol rocks, instead of exclusively the great Infra-Blini series. The change is introduced below the confluence of the Palar and Giri. The Blini conglomerate is found high on the summits over Railu, and Shengri; more to the east, in the same line, it is met with in the gorge north of Gailu, and in the gap between Geruani and Juin. From Shengri to the Olong peak the section is very similar to that between Keari and Tara Devi; schistose slates, graphitic, micaceous, or quartzose, alternate, with a variable low northerly dip. On the north-north-west spur from Olong they are capped by a considerable thickness of dark earthy limestone. North of this spur, deep in the gorge of the Palar, we again find the slates and grits nearly horizontal, and on the ascent to Chorna the graphitic schists are repeated, but here they are surmounted by hornblendic and felspathic strata,—possibly the earthy limestone altered. North of Chorna there is a band of coarsely crystalline, white limestone.

Continuation of Krol group.

We can still follow up the Krol group with some certainty. The Giri, below its confluence with the Jalar, flows in a more easterly direction, and still along an anticlinal, the Blini limestone showing itself at intervals. North of this part of the river we find, in the Juma ridge, the modified continuation of the limestone range to the north-west. On Juma most of the Krol rocks can be recognized, though greatly more contorted and obscured than at any point west of the Giri; the limestone is often a white marble. To strengthen this identification we find the Blini limestone again in the valley to the north of the ridge, under Koad.

In the hills north of Koad there is a note-worthy example of variability in the rock which I suppose to represent the upper Krol limestone. In the valley the Blini group is well exposed; on ascending to Jerrog dark slates and grits have a steady northerly underlie; at Jerrog there is a band of thin compact limestone, over this come more shaly slates, with fine, crumbling, earthy, calcareous beds. The dip gradually diminishes to a low angle. So far we have a very fair representation of the Infra-Krol and lower Krol strata, except in the absence of the Krol sandstone, in its normal position. Conformably resting on these beds, and with the same low northerly dip, we find, forming Kerloe peak, some six or eight hundred feet of thick clear sandstones, with occasional shaly partings, and at the summit of the peak just a remnant of hard, cherty, sandy limestone,—a typical upper Krol rock. Besides the evidence of this hard, sandy limestone, I found, in the extension of the same band to the eastward, that in many cases beds of sandy limestone occur through the more purely arenaceous strata, so that it seemed to me that this band was not to be considered so much a newly intercalated member of the series as a local modification, and a true equivalent of the upper Krol limestone. Far to the west, about the Sutlej, I shall have to call attention to a similar fact, in what I suppose to be the same set of beds. Immediately north of Kerloe peak there occurs a line of great contortion. The sandstones turn up in a uniclinal curve to nearly vertical, and are then folded over on themselves again by a sharp anticlinal. Along the line of gaps on the southern spurs of Guma ridge, to the north of this arenaceous band, beds of black and calcined shaly slates are again brought in, dipping northward under the limestone which forms the Guma ridge.

Near Koad.

Kerloe Peak.

Guma ridge.

In descending into the valley of the Neweli from the west, one passes downwards over a thick section of slates and grits. The valley is denuded along a flat anticlinal, the axis of which slopes to the north of west; the strata on the north incline more to the north-west, and those on south to the west; about Batewli there is a considerable thickness of black, ferruginous, and flinty slates, and they are succeeded by a great thickness of hard, clear, finely granular limestone, sometimes very compact. Below it, under Othri, there is a conglomeritic band among the slates; it may represent the Blini group. This great limestone in the Neweli is no doubt the same as that seen more to the north in the Suinj. In both sections, as so often elsewhere, we are confronted by the difficulty of the apparent intercalation of our supposed uppermost rocks with strata, which in less troubled sections seem to underlie them. A few weeks' work on the hills about the head-waters of the Neweli, the Bungal, and the Suinj ought to throw much light on this important question, as well as on that of the granitoid rocks on the summit of the Chor, and with which it is connected. I hope that the few indications I have given will at least show what are the difficulties to be encountered.

Valley of Neweli.

Whatever links in geological structure we may establish between the Chor mountain and the Himalayan range in general (and these links are not few), this mountain has a very decided individuality of its own, of which I am at a loss to give

Structure of Chor.

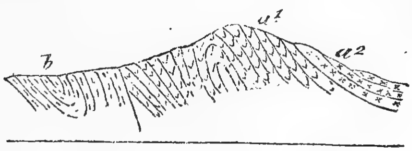
a satisfactory explanation. Indeed, until this special question of the formation of the Chor be settled, it would be idle to speculate upon the relation which this bears to the more general one of the Himalaya range at large. The Chor now stands within, or rather at one side of, an area of special elevation: immediately to the east of it the upper rocks of the Himalayan series occupy a wide area in the Lower Himalayan region; while to the west, at and above the mean elevation of the hills, we find the lower members of the series, although at Simla we found evidence that the upper beds had once existed throughout. A leading question to be determined with regard to this area of special elevation is:—has it any lines of maximum intensity, and where are they? In the south-west portion of the area there can be very little hesitation in placing such a line near the great fault. The action along this fault seems to have extended with undiminished intensity to as far as the confluence of the Giri and the Palar, and in this region it is confronted by the Chor. The features I have described on and about the Chor warrant, I think, the inference that it has been a focus of activity, but it is still an open question whether or no special elevation is involved. The fact that this point is now the highest summit in the district does not affect the reasoning; it will be evident that this may be due to the action of denudation,—the Chor may in reality have been a focus of depression. In the absence of recognizable stratified rocks, the question will turn upon the view to be taken of the central granitoid mass,—whether it has resulted from the elevation of a more deeply seated metamorphic rock, or whether it be a simple intrusion, in the more exact meaning of the word, of a more or less plastic rock. In the former case we should have to regard the Chor as a most remarkable instance of special elevation, while in the latter case its special depression might be surmised. The lithological and special structural characters of the granitoid mass are against the probability of its origin from fluid intrusion. The exception on the north-east side to the

Lines of intensity of disturbance.

convergence of dip that forms so peculiar a feature of the region round the Chor, seems to me strongly in favour of a faulted elevation and semi-intrusion, such as I have attempted to represent in Fig. 6.

FIG. 6.

S. W. N. E.



Conjectural section of the Chor Mountain.

The probability of this mode of explanation is greatly strengthened by the analogy of other sections. On the Dhaoladhar there is a section very similar to that of the Chor; there, however, we have a very long and straight range, in which case there seems nothing forced in supposing it to be the result of a great, faulted, anticlinal flexure; whereas, whether going north-west or south-east from the summit of the Chor, we should be obliged to suppose a section similar to that I have shown on the south-west, and at about the same distance from the summit,—a kind of button-like intrusion, of which it is difficult to conceive the possibility without considerable plasticity in the mass, or indeed even granting such plasticity. To this however we find also an analogy in the Dhaoladhar: at the abrupt termination of this great ridge of granitoid rock, over the bend of the Ravee, we find the flanking schist rocks to curve round, and to dip under the *end* of the ridge as steadily as they had done along its southern base. If then viewed as due to the elevation and semi-intrusion of a normally underlying mass, the upheaval or tilting in the Chor must be at least 10,000 feet greater than anything that occurs along the Giri fault.

Simla synclinal.

The Simla synclinal axis, if continued, would pass on the south of the Chor. In the north-west direction it points to, and reaches the farthest limit of the partial area of elevation. In the amphitheatre of hills west of Sukrar we first find

the western termination of the synclinal axis, forming a three-sided converging dip; the ridge of Gharog belongs to the south-south-west dip of the Simla ridge, of which watershed it is a branch continuation. For several miles in the same direction, this acute curve in the strike obtains, until at last the sides of the synclinal come together, so that the reverse dips form a general anticlinal down the valley of the Ulley. With this synclinal the partial area of elevation terminates. It must be remembered that it is only as belonging to the outer belt of the Lower Himalaya, as compared with the country to the south-east of the Chor, that this area can be spoken of as one of special elevation. We have seen in the section from Simla to Hatu a steady rise in the rocks as we proceed north-eastwards.

Dies out west of Sukrar.

In the valley of the Sutlej, to the north of Simla, we find a good example of the deep indentations in the older rocks occupied by younger strata. The south-south-west dip at Simla, which to the east-north-east passes by a uniclinal, rather than an anticlinal, curve into the undulating eastern inclination at Mahasu, is maintained on the north down to the Sutlej valley, through a descending section of the Simla slates, or Infra-Blini series. A strong band of slightly micaceous sandstone occurs at Bogora, the slates in contact being sub-schistose, as is usual in such positions. On the spur from Mahasu the dip flattens greatly, but soon rises again in the same direction along the ridge over Basantpur. A thin band of limestone shows here on the crest, passing obliquely into the valley on the south. On the north side are more slates, greatly crushed towards the base. In the area represented approximately by the actual gorge of the Sutlej, utter confusion pervades the rocks; ribs of massive limestone strike up promiscuously among slates and sub-schistose rocks; there is also much trap rock. Below Suni a copious hot spring rises in

Valley of Sutlej.

Area of disturbance.

the very bed of the Sutlej. This area has been no doubt a focus of intense local disturbance, and of accompanying igneous intrusion.

It will be recollected that, on the section described from Simla to Hatu, passing at only a short distance to the east of the section I have now brought to notice, and right across the direction of this axis of disturbance, we found no sign of similar conditions; a general easting in the point of dip was the only noticeable change. The Shali mountain, the peak that forms so prominent an object in the middle landscape as one looks northward from Simla, stands at the eastern focus and terminus of this line of disturbance. It attains an elevation of 9,420 feet, while the Sutlej, only five miles distant, flows at a level of about 2,500 feet. The stratigraphical conditions have aided to make the most of these circumstances of elevation; massive bands of limestone are tossed about in every direction; the crumpled slate rocks have yielded easily to denuding forces; thus producing a combination of deep narrow gorges and of lofty rock cliffs, which are densely covered with forest on every available spot.

Shali mountain.

Its wild scenery.

In going from Shali to the south, to the east, or to the north, we find the same rocks have assumed a steady diverging dip. We have seen how it is to the south. The connecting ridge between Shali and Tikar is formed by the massive limestone, and its associated quartzite-sandstone, having a south-easterly dip. On Tikar this has become easterly. In the valley about Darampur or along the ridge over Runi, this rock is overlaid, at an angle of 20° to 30°, by schistose slates. Over a variable thickness of these slates there occurs a thin band of limestone, often of a slaty aspect; it is worth noticing as forming a pretty constant feature in these sections; and in places, as for instance east of Runi, it has reminded me of the Kukurhutti limestone, to be presently mentioned. Hereabouts it is overlaid by the siliceous schist of Theog and Muttiani. The same section may

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be equally well seen about Baot, in the valley to the north of the ridge over Runi.

North side of Sutlej.

Along the north side of the Sutlej valley the position of the limestone is better defined than on the south. There is an excellent section in ascending from Malgi to the Dhamun Nag summit. The independent hill of Balu, rising nearly as high as Dhamun Nag, from which it is separated by a deeply cut gap, is formed of the massive limestone. The Sutlej at Malgi runs over thin-bedded, pink limestone, with slaty partings, and having a dip of 70° or 80° to north 10° east, but exhibiting also frequent sharp foldings on the same strike. These beds reach to about half the height of the hill, where the dip is reduced to about 60°. On account of the contortions in the lower part of the section, the exact thickness cannot be ascertained; it can hardly be less than 1,200 or 1,500 feet. The thick siliceous limestone succeeds, and at the summit it inclines at 40° to north-north-east. There must be at least one thousand feet of it. Along the descent to the gap leading to the Dhamun Nag the limestone is found to be overlaid by brown and dark blue slates, and with them is a band of slaty limestone. These thin-bedded rocks are, of course, more or less contorted, but they have a marked general northerly dip. At the gap there is a strong rib of quartz along the strike, and immediately north of it, on the rise to Dhamun Nag, schistose slates appear, much veined by quartz, and having a lower and steadier dip in the same direction as the rocks to the south. Along the ascent they become more metamorphic, and at about a third of the height the coarse gneiss shows, its massive beds dipping at 40° to north 10° east.

Malgi and Dhamun Nag.

Junction not a simple fault.

As it appears in plan, the section suggests the existence, along the gap, of a faulted junction. But besides the fact that this more abrupt junction, with a separating vein-rock, is an exceptional appearance along this boundary, we have at this place other facts to throw doubt on such a suggestion. The feature already described on the south of the Chor, as indicating the general underlying position of the less altered rocks, is equally well marked in the similar instance of this boundary, and no where better than in the valleys to the east and west of the Dhamun Nag mountain. On both sides the junction forms a well marked angle up the valley. Moreover, there is much likelihood that the slates, and slaty limestone which, in the Dhamun Nag section, certainly rest upon the great limestone and conform to its condition, are the same beds as those noticed about Runi in a similar position, but at that place most certainly underlying the siliceous schists, and partaking of their condition.

Gairu mountain.

With slight variations the section along the north of the Sutlej valley to the westward, as far as Gairu summit, is similar to that I have described south of Dhamun Nag. The strike in that direction becomes more northerly. In some places, as in the great cliffs below Odittana, the gneissose rocks reach to within a few dozen yards of the limestone. At the southern bend of the Sutlej, at Boh, the thin pink limestone and variegated slates underlie at 80° to the north-east; the gap of Butwara is formed in them. Along the western shoulder and on the summit of Gairu the massive limestone, with its associated pink and white quartzite-sandstone is greatly rolled about, often dipping east and south-east; along the ridge to the east dark shaly slates with much trap-rock are similarly disturbed. This run of trap-rock is very steady in this

position for some distance to the east, as far as Bhalana. On the summit west of Judare the limestone and sandstone come in again with a dip of 50° to the north-east. A short way to the east, south of Kune, the gneissose rocks form the main ridge, having a moderate north-easterly dip. Thus Gairu stands at another bend of the boundary and exhibits the irregularity of disturbance usual in similar positions elsewhere; and here, as elsewhere, the actual boundary curves round with a regularity that is most remarkable when we consider the nature of the junction.

For some distance to the northward from Gairu, I have no knowledge of this boundary of the Shali (or Krol) limestone series with the metamorphic rocks. The narrow outlying band of the Krol rocks, which towards the Sutlej bounds the region of the Subathu group on the west, exhibits the same general features of disturbance as have been described to the east of this region; the strike of the beds in that outlier corresponds throughout with the direction of the ridge, which, being a well defined line on the map, exhibits that feature clearly.

Outlying ridge of Krol rocks.

The stratigraphical phenomena which I have attempted to describe in the last few paragraphs form a companion puzzle to what we have seen on the Chor. There we had a three-sided convergence of dip upon what seems to be a point of special elevation; here we have a three-sided divergence of dip in what seems to be a band of special depression. I assume in both cases, what I think is most probable, that the limestones are the representatives of the Krol group. How (keeping in mind the magnitude of the section) these limestones of Shali became so deeply let into this inverted trough of older strata, is more than I can at present explain. If the east end of this trough were an ordinary fault, or a rapid elevation and truncation of the calcareous strata, the case were comparatively simple; but it is not so; the abnormal superposition of the older strata is as regular on the east as on the north.

It is not easy to account for the features of even a single section of the junction, such as that through the Dhamun Nag. It is not a case of simple inversion: the contiguity of the extreme types of rock involves faulting, or some equivalent supposition; and the direction of the plane of contact necessitates *reversion*, that is, a slope opposite to that which is considered normal in cases of faulting, with reference to the relative positions of the younger and older strata.

FIG. 7.

Crush-rock. Trap-rock.

Section from Simla northwards, across the valley of the Sutlej. *a.* Schists. *b.* Slates. *c.* Krol group.

Reverse faults.

The most probable explanation, with which I am acquainted, of reverse faults, of which we meet such frequent apparent instances, and on such a grand scale, in these Himalayan sections, producing the superposition of older upon younger strata, is that of Prof. Rogers (see appendix), in connection with the folded flexures of strata. It is a kindred phenomenon to that of *fan structure,* of which so many examples have been observed in the Alps, and other regions of disturbance. The lateral force, which is obviously required for these flexures and inversions of strata, seems competent to produce such faulting ; but this explanation involves, at least in its typical mode of action, the inversion of the beds on one side or the other. In the case of the Dhamun Nag section the low steady dip of the older rock would point to a fault along an *anticlinal,* thus entailing the inversion of the upper beds on the downthrow side of the fault. But, if the identification of the series be correct, this is apparently not the case ; the thin-bedded, compact, pinkish limestone must represent the lower Krol beds, and they are, to all appearance, in the section north of Malgi and elsewhere along

First hypothesis.

the Sutlej, in their normal position with respect to the more massive siliceous limestone above. However, the contortion of these upper rocks in the Sutlej valley is so great that in a rapid survey, such as mine has been of the lower Himalayan area, one must indulge a little in inference when facts are deficient. Fig. 7 represents a conjectural section from Simla northward across the valley of the Sutlej.

Section from Simla across valley of Sutlej.

There is another mode of explanation which has many times occurred to me as plausible. In describing the Sub-Himalayan rocks, we will frequently meet with this same appearance of superposition of the older upon the younger strata; in fact, it is the rule in all boundary sections, and under conditions when reverse faulting, or in some cases faulting of any kind is inadmissible. May not the explanation of those cases be applicable here also? May not these upper beds of the unaltered series have been deposited against a steep cliff of the older rocks, or even in a deeply cut valley in them? Under subsequent lateral compression the newer rocks, and the upper strata yield most, and an overhanging junction might result. But this involves a very extensive unconformity of the two series of deposits, of which, in the present case, we have no direct evidence. If the question were only between the limestone group and the gneissose rocks, there need be little hesitation in provisionally assuming this utter unconformity, but the apparent superposition is often almost as marked between the limestone and the Infra-Blini series, and we have already seen in the Simla section what we suppose to be the Krol group resting upon the slate series with every appearance of true conformity. Whatever explanation we can give of the abnormal junction of the Krol group with the slates will also apply to that with the gneiss.

Second hypothesis.

The adoption of the opinion that these limestones of the lower Sutlej valley, and those in the Suinj and Neweli to the east of Chor, are not the Krol group, but much lower in the series, would only give very

partial relief; the evidence is equally strong for their infra-position to the gneiss and schist series; but such a supposition as this is still repugnant to our well-founded geological ideas. Here again what explains the one will explain the other. The subject will come before us again.

Limestone ridge north of Erki.

In the case of the great limestone bands to the east of the Chor we were able to trace into their vicinity the undoubted continuation of the Krol group, and thus to strengthen the independent evidence for the identity of the two. In attempting to do the same for the area of the lower Sutlej we encounter extra difficulty instead of support. The Krol group is entirely cut out to the west of the Boj; and with it disappears the rugged ridge which is elsewhere so general a feature at the outer limits of the Lower Himalayan region. Beyond Erki, sixteen miles to the north-north-west of the Boj, a fringing ridge of limestone appears again, occupying the same position in the section as the ridge of the Krol rocks to the south-east; and this limestone is undoubtedly the same as that of the Sutlej valley.

Kukurhutti limestone.

If the interruption of the limestone ridge between the Krol and Erki were more complete than it is, we should have less hesitation in supposing the rocks to be identical; for, in the intermediate ground there is an apparent link which only adds to the puzzle. At and south-east of the parade ground of Subathu, the nummulitic rocks and their overlying red sandstones form the whole ridge. To the north-west, grits and slates, some sub-schistose, weather out along the point of the ridge. Among these thin-bedded rocks a limestone soon makes its appearance, becoming gradually more prominent as the ridge decreases, till at the Ghumber there is nothing else left but this band of limestone from fifty to one hundred feet in thickness. Its lithological peculiarities can be well seen along the road-side just north of Kukurhutti. It is remarkable for the very deceptive appearance of organic forms that occur so generally in it. They are

principally of flat circular shapes. I have pored over this rock for hours in the hopes of discovering some recognizable and reliable form : repeated failure has left little doubt on my mind that the whole are of inorganic origin. The strike of these rocks here is about south 30° east, with an average prevailing north-easterly underlie. The most unequivocal section I have seen, as exhibiting the position of this limestone, is in the gap through which the road from Haut passes to the westward. Here the thin band of limestone is well seen to rest upon, and to be overlaid by sharply bedded grits and slates. Some of the overlying grits expose beautifully rippled surfaces. On this section the rocks, as a whole, have a steady dip to the east by north, the same being maintained in the section to the east; and on the road leading up to the Sairi hills, about Bil, the Blini limestone and conglomerate are several times repeated by contortions, in a precisely similar manner as on the spur north of Haripur. I may mention that this is the most westerly locality in which I have noticed this important band of rocks.

Its connection with the great limestone.

On the ground of its lithological peculiarities alone one might, I think, decide that the Kukurhutti limestone does not belong to the Krol group ; at least it is not distinguishable in the typical sections of that group a short distance off. The strata with which it is associated are also of the type of lower rocks; its apparent position in the section being far down in the Infra-Blini series. It seems too as if the general elevation of the outermost belt of hills, to which elevation and its consequences the removal of the Krol group at this point may be attributed, had brought up lower beds here than elsewhere within this zone. Yet this Kukurhutti limestone is continuously traceable along a chain of low hills into the great limestone range north of Erki, where it seems to be associated with the massive limestone; the rocks, however, are all so very much disturbed that it will be difficult to establish their true relative positions. It may be worth mentioning that I detected the peculiar quasi-fossiliferous

character of this (the Kukurhutti) limestone in the thin overlying band near the boundary, east of Shali, over the village of Runi; and, what may be more important, I noticed the same characters in a limestone about Oniar in the valley of the Tons. Altogether, a very strong case can be made out for considering these limestones of the lower Sutlej area distinct from, and much older than the Krol group; yet, in the present state of our knowledge of these rocks, I prefer to accept provisionally the more general argument in favor of their identity. In examining this region I was perpetually struck by the great lithological resemblance and analogy of arrangement of the strata with those of the Krol series. There is the massive, and often siliceous limestone, frequently sandy, and passing into sandstone, underlaid by thin limestone, with variegated shaly slates. The non-appearance of the Blini limestone, so constant in the sections to the east, may be accounted for in many ways, even if the presence or absence of so subordinate a member were of much weight. I can even point to a possible representative of the Blini group; north of the Sutlej, on the spur north-west of Bihul, in contact with a strong dyke of trap-rock, there is a small thickness of coarse quartz conglomerate, overlaid by slate and thin-bedded limestone. If then the limestones of the Sutlej valley be Krol rocks, the whole group must be supposed to have undergone less elevation than elsewhere; the underlying rocks are less exposed than in the region to the east.

Supra-Krol.

There is another point to be noticed in connection with the subject of the last paragraph. It must be recollected that the fact of no rock appearing above the Krol group, where the section of that group is best exposed, gives neither evidence nor even presumption that these rocks are really (in any strict sense) the top-rocks of our unaltered series. If the limestone of the Sutlej region be taken to be of the Krol group, it would remove some of our difficulties to suppose the limestone at Kukurhutti, and its representatives elsewhere, to be a supra-Krol band.

Area of the Beas.

In the region of the Beas and its tributaries we have a repetition, on a larger scale, of the structure I have described in the valley of the Sutlej,—an irregular basin of the upper, unaltered rocks. It will be seen from the dotted line on the map that the boundary is put in conjecturally. I have only crossed the district once, along the road from Simla to Sultanpur, but the section then examined is sufficient to show the strong similarity of the features to those seen in the Sutlej valley. In the basin of the Beas the boundary rock on all three sides is gneissic. Of the great mass of mountains, of which Cheru, Shinaridevi, and Chigera are the principal summits (all over ten thousand feet in elevation), I have no direct observations to record. We have seen that gneiss rocks reach far down on their southern and south-western spurs over the limestone area of the lower Sutlej. The section from Kotgurh to the Beas, crossing this mountain tract by the Jalori pass, will afford a view of the probable condition of the whole. The gneiss rocks of this region form by no means so uniform a mass as that described on the Chor. The gneiss on the summit of Hatu shows the same conditions as that to the west of the Sutlej. On descending from Hatu through Kotgurh to the Komarsin bridge, or on going from Narkunda over the summits to the west, and down the Shengri spur, to the same point, I noticed no felspathic rocks; crystalline schists of both siliceous and earthy types occupy the whole section; it is even remarkable that the lower beds, under Komarsin, are often more slaty than schistose, and, in that state, are generally also carbonaceous or graphitic, decomposing into a sticky black clay. The softer varieties of schist often exhibit great local contortions, but a general moderate inclination is traceable throughout, varying to between north and east. For about eight hundred or one thousand feet over the Sutlej the gorge is cut into massive porphyritic gneiss. The bedding is very distinct, showing a low, undulating dip to the northwards.

On the section from Komarsin bridge to Jalori there are numerous instances of true gneiss, interbedded with the schists. There are several such bands through the schists below Dularsh. At the stream north of the Kando gap there is some very massive and granitoid gneiss with a steady low dip into the ridge to the north-east. Graphitic schist shows near Bushlani. A low west by south dip obtains on the spur of Purgot. On the main ridge at Jalori siliceous schists dip at 40° to 50° to south-east. On the descent from Jalori to the northwards the rocks are greatly concealed by mould, which very commonly, as here, lies deep on the forest-covered northern slopes. In several places soft schists are exposed, and are frequently highly graphitic. At a few hundred feet over the valley, some thick-bedded, clear, sub-crystalline limestone crops out in the midst of graphitic and soft micaceous schists. The dip is here south-westerly. About Gag the same beds underlie to the north-east. About Rusali strong bedded quartzite-sandstone dips at 40° to the south-east; and on the ridge above these beds form fine cliffs, with the same dip. Under this band of hard rock there is a great thickness of fine, soft, argillaceous, and sub-foliated slates, in which a green variety, and also the graphitic variety, are conspicuous. As seen on the base of the spurs, and in the valley below Plach, they exhibit much crushing with variation of underlie, yet having a prevailing southerly direction on the south of the river, and an easterly direction on the north of it. Trappean intrusions are large and frequent, as is well seen about the bridge above Manglour. From a short way below Manglour the river passes through a great band of limestone, often thick-bedded and sandy, with grits, and dark and pale red slaty shales. In the short gorge between the confluence of the Teerthun and the Synj at Largi, and the confluence of

the combined streams with the Beas, there is a good section showing repeated alternations of arenaceous, argillaceous, and calcareous strata, having here a prevailing high underlie to the north-east. These limestones and quartzose rocks form the hills on the east of the Beas, with an east-north-east dip. At the base of Phugni, north of Sultanpur, siliceous mica-schists have a variable underlie to the north and north-west: at about three thousand feet up there is a band of porphyritic gneiss ; it is overlaid by graphitic and ferriferous schists. On the summit there is a considerable thickness of fine siliceous schists in thin and thick beds, and having a steady dip of 45° to north 30° east. This northerly dip seems to obtain here on both sides of the Beas. In crossing the ridge on the west of the valley, by the road from Bajaora, green slaty schists appear at the lower end of the gorge with a high westerly underlie ; but within a very short distance they give place to gniessose rocks. The ridge is, in fact, formed by this rock with its associated siliceous and micaceous schists; the dip is inward and northwards on both sides, producing an irregular synclinal with a northerly inclination of the axis.

The same general argument may be applied here, as in the Sutlej area, for supposing the limestone, and the beds immediately associated with it, to represent the Krol group. The fine green earthy rock, so frequently sub-schistose, is a new introduction or else a modification of the dark, shaly slates ; indeed, all the rocks of this area are more altered than those of the Sutlej valley. In respect of structure, the rule is as strictly observed here as elsewhere of dipping towards the nearest ridge of the older rocks. A first impression of the section, both on the ridge of Jalori and on that over Bajaora, would be, that the gneissic rocks were underlaid throughout by the limestones and slaty rocks which seem to crop out from beneath them on either side. The fact just noticed establishes a contrast, which may be a very significant one, between these ridges of gneissic rocks and the granitoid masses of the Chor, and of the Dhaoladhar, as presently to be described. In both these latter cases the schistose and slate rocks on the north rest upon, and are *inclined from* the ridge of granitoid gneiss rock ; in the former they appear to dip under the similar rocks.

In the fringing band of upper rocks in this portion of the Lower Himalaya, we find a departure from the type of the Krol section, corresponding with what has just been noticed in the valley of the Beas. From Suket northwards, trap becomes a dominant rock along the boundary. It shows a general conformity in direction to the strike of the strata, *both* agreeing with the direction of the boundary, which is here often to east of north. The continuation westward of the section along the road across the ridge, from Bajaora, will exemplify this statement. About Sandoa there is an abrupt change from the gneissose schists of the ridge, to very dark, carbonaceous, and ferruginous, shaly rocks, often very hard and flinty; they are nearly vertical, having but a small underlie to east 10° north. Without any marked variation of character these rocks continue the whole way to the Ool, a distance of about four miles across the strike ; the foldings are so complete as to escape detection. This band of rock is just such as might result from a greater development of the Infra-Krol shales. In the immediate valley of the Ool, trap-rocks are extensively exposed, and of numerous varieties, compact and vesicular. On the steep ascent to the west clear quartzite-sandstones, with occasional partings of pink and blue slate, show a broken, westerly underlie : but, on the whole, trappean rocks predominate in this ridge, the slates and quartzites being rather intercalated in the trap than the trap in

them. Trappean metamorphism has also operated largely, producing intermediate varieties of contact-rocks. Close along the western base of this ridge we come upon our main boundary, the inner limit of the Sub-Himalayan rocks. The special features of this junction will be described elsewhere; I may now, however, mention that a limestone almost invariably occurs along it among the inner rocks, and still showing features in common with the upper Krol rock; for example, at Badoula, a few miles to the north of our last section, about one hundred feet of blue, compact, cherty limestone is underlaid by greenish and pink quartzite sandstones, and red shaly slates.

The next section that I have seen of these outermost rocks is at the extreme north-westerly limit of the lower region of the Eastern Himalaya, and where we find first established in those rocks the conditions which remain constant throughout the whole length of the Dhaoladhar range.

Western limit of the Lower Himalayan area.

North of Haurbagh (Hurribagh), about Wyre, the outer rocks of the section are concealed. The first rocks that appear are trappean schists, having an east-north-east underlie, often at a moderate angle. At about a third of the height these are apparently overlaid by gray quartzites, and these pass transitionally by alternation into siliceous mica-schists; all having a moderate dip into the ridge. The schists graduate into the massive porphyritic gneiss that forms the crest, where the dip is high to the north-east. Schorl is common in the gneiss. The deep gorge of the Ool is here formed in fine, soft mica-schists, with a south-south-east strike, and a variable underlie. It seems possible that these argillaceous schists may represent the broad band of carbonaceous slates noticed below Sandoa: the general analogy of other sections would, however, lead me to expect that it is not so,—that the boundary remains as distinct as usual, and that the metamorphic rocks of the higher ridge to the east of the Ool gradually encroach to the westward until, as just described, they occupy the valley and the outer ridge. In the Ool at this point trap-rocks are absent, as is almost always the case in the crystalline metamorphic rocks. Over the villages of Diot, Darmaun, and Milan there is a band of schist, largely charged with magnetic iron ore, which is extensively worked. In re-crossing the ridge from Kohad to Beer the section is very similar to that above Wyre; but here the

crystalline rocks reach much lower down on the south side. There is massive granitoid gneiss at Sulhetur. Here too the trappean schists, below a well marked boundary with granitic rocks, are themselves felspathic, and even porphyritic.

Salt rocks of Mundi.

In connection with this portion of our area I must notice the well-known salt rocks of Mundi. I approached these rocks with various expectations. Any mention that had been made of them by geological observers in India treated these salt rocks of Mundi as beyond question the geological equivalents of the salt rocks of the Punjab. It was indeed plain that the opinion was rather taken for granted than founded upon evidence, yet the notion was sufficiently plausible to excite hopes of finding something new, and which might throw a light upon the general section. My curiosity was increased by the fact, that the same authorities alluded to the Mundi salt as connected with the red clay and sandstone deposits, which I have grouped in the Sub-Himalayan series, although for many years it has been known, from Dr. Fleming's descriptions, that the salt of the Punjab occurs in Palæozoic (Devonian) rocks. The imaginary puzzle was of course removed by a single inspection of the ground, but only to make way for a real one. I can state that the salt occurs very close to, but well inside, the main boundary, among the limestone, sandstone, and slates which I have supposed to be the same as the Krol rocks, and which are here much complicated by trappean intrusion : but the natural history of the salt is still very obscure.

Position of the mines.

There are at present two localities where the salt is extracted ; one just below Drang, and the other fourteen miles to the north, at Guma. Both are at the base of the steep and regular ridge, formed principally by the trappean rocks, along the boundary of this region of the Himalaya. In both cases the workings are placed right in the bed of the drainage gullies : whether or not this is a necessity entailed by the local distribution of the mineral I have no means of ascertaining ; but think it is not. These difficulties, natural or presumed, backed by improvidence and want of skill in the native managers, result in the almost total stoppage of the works during the rainy season, in the almost total destruction and obliteration each year of the open pits and short galleries by which the salt is extracted, thus involving the annual execution of these preliminary operations, which are sometimes very difficult. As may be expected from these facts, the opportunities for examining the *allure* of the mineral are very poor. The Mundi salt is commonly known in the neighbourhood as black salt ; it has a dark purplish hue, is quite opaque, and contains a large admixture of earthy impurities. An average sample gave twenty-five per cent. of earthy matter. The salt is pure chloride of sodium. It is only used by the poorer classes, who, as a rule, subject it to a purifying process by fire and water. Small nests of pure crystalline rock-salt are occasionally found, but so rarely as to be reserved for the special use of the Rajah and his household.

Quality of the salt.

Regarding the origin of this rock, we have to select one of these views,—contemporaneous deposition pseudomorphism, or, a totally subsequent introduction ; we will see that the

evidence is very conflicting. First let us consider the lithological evidence. The arrangement of the earthy matter in the rock bears very strong testimony to a sedimentary origin: besides the diffused earthy matter there are always present fine laminæ, or very thin continuous layers of clay, which exhibit a coincidence in strike and dip with those of the associated strata. Another important characteristic of this salt rock is the occurrence through it of small angular pebbles; they are irregularly scattered through the mass. Out of a number of these pebbles most were recognizable, with much probability, as of the rocks immediately associated with the salt, pink quartzite sandstone being the most frequent; some are of limestone. The evidence of these pebbles is however not all on one side of the argument. If they be really fragments of the Krol rocks, the salt deposit cannot be cotemporaneous with that formation; nor yet can it be pseudo-morphosed limestone of that formation; on the other hand, the tolerably uniform distribution of these pebbles in the mass, and their uniformly small dimensions are opposed to the supposition of the rock being, in any sense, the result of forcible crushing.

Origin of the salt.

We may next examine the circumstances of position. Besides the accidental fact already noticed in the position of this salt rock,—along a line at a distance, varying from one hundred yards to a quarter of a mile, from the boundary of the Sub-Himalayan rocks, there is an important constant peculiarity, resulting in a feature of contour too small to be shown on the map. From the main ridge short spurs or head-lands project at intervals; towards their extremity, these expand longitudinally, so as to form rather flanking hills than true spurs, and are connected with the ridge by a line of gaps. The drainage of course follows the physical features,—the several small streams bifurcate into these small longitudinal valleys. The rocks of this outer belt are not the same as those of the main ridge; limestone predominates. It is associated with red and brown slaty shales, all greatly contorted along a general north and south strike. In the main ridge, as already stated, trappean rocks prevail. The salt rock occurs along the contact of the main and minor ridges. It did not appear to me that this line was a fault line, at least there is no sharply defined fault: highly foliated hornblendic schists and quartzites appear sometimes outside (west of) the salt rock, and also remnants of limestone to the east of it. Both these cases occur at Guma. Peculiarities of position, such as are pointed out in this paragraph, suggest an adventitious origin for the saline element.

Some peculiar rocks associated with the salt rock give us a third item of evidence. In contact with, or near the salt rock, there are always to be found varieties of rotten rock, showing different degrees of resemblance to the salt rock itself, often having the appearance of being only varieties of that rock from which the salt had been dissolved out,—it is a *salt-gossan*. In connection with this rock, supposed to be a weathered residue of a saliferous rock, there occurs an undecomposed rock, which strongly resembles the true salt rock. For example, in the Suketi at Mundi, a few hundred yards above its confluence with the Beas, the massive Sub-Himalayan sandstone is vertical, with a strike north 10° east; in contact with it is about fifty feet of sandy limestone; next to this follow about one hundred feet of the bright red calcareous, earthy, pebbly rock, the representative of the salt rock; next to it comes massive trap-rock. Again to the north, in the river east of Beer, this peculiar rock,—the salt rock, but with the salt represented by carbonate of lime,—occurs twice in the same cross section, associated with the usual limestone

and trap-rocks. The facts here noticed leave scarcely a doubt that there is in this portion of the area a stratified rock, possessing peculiar original characteristics: that it is at one place saliferous, and at another calcareous, strongly suggests the question whether the saline quality be not also one of its original, local peculiarities. So far as trap-rock can be taken as an exponent of a metamorphosing agent, its influence should have been as potent at either of the two last-mentioned localities as where the rock is saliferous. On the whole, I think that the balance of evidence is in favour of the cotemporaneous origin of the salt.

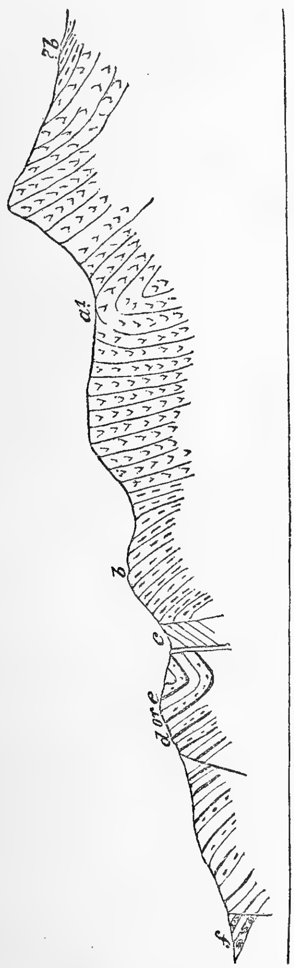
Section of Dhaoladhar at Dhurmsala.

I have now to notice the region of the Dhaoladhar, in which we find conditions in some important respects markedly different from anything described among the lower region of the Eastern Himalaya. The section already given of the ridge west of the upper valley of the Ool is very similar to what we shall find along the base of the range, up to the Ravee. North of Soonsal, Dewal, and Lonode the narrow band of limestone, a quartzite sandstone, and calcareous slates, which are also often carbonaceous and with more or less of trappean rocks, appear to underlie the mica schists and gneissose rocks of the lofty spurs from the Dhaoladhar. At Bundla the trap-rock is again more abundant, and with numerous symptoms of the saliferous rock. North of Nirwaneh the band of limestone and pink shales with trap, outside the great schistose series, is still very narrow. At Dhurmsala limestone is well seen, and its relation to the schist series is more distinctly defined than usual. At the village of Bagsoo, in the gorge north-east of Dhurmsala, thin-bedded, blue, compact limestone has a dip of 70° to the south-west, being also crushed and contorted. This is just to the north of the sandstone ridge on which the station is built. There is little or no trap. About forty yards north of the limestone the schist series is seen, with a broken high dip to north. The dip in these fine, greenish, micaceous schists becomes flatter and more steady in ascending the spur. On approaching the great buttress of massive granitoid gneiss, standing out from the main ridge of the Dhaoladhar, the dip again rises, and thus the schists seem to pass under the more highly crystalline rocks. There is little change in this rock up to the crest of the Dhaoladhar.

The foliation, and the changes of texture and of composition, indicate throughout a high underlie to north-north-east. From the top of the ridge at the Murrumghattee I saw to the east and the west, reaching high up on the northern spurs, thin-bedded, dark-coloured rocks, apparently but little metamorphosed, and resting at a moderate inclination upon the granitoid rocks. Fig. 8 represents the features of this section.

FIG. 8.

N. N. E.



S. S. W.

KANGRA VALLEY. BAGSOO OR DHURMSALA. MURRUMGHATTEE.

Section of the Dhaoladhar, north of Kangra. *a.* Gneiss. *b.* Schistose slates. *c.* Krol group. *e.* Lower Sub-Himalayan. *f.* Sivalik.

Section by Choari and Chumba.

To the west of Dhurmsala the Sub-Himalayan boundary recedes slightly southwards; the area to the south of the Dhaoladhar, occupied by the outer rocks, being much wider than at Dhurmsala. This expansion occurs principally in the calcareous, slaty, and trappean series. The trappean rock here, as elsewhere, shows a disposition to keep separate rather than to mix indiscriminately with the sedimentary rocks, but throughout this area west of Dhurmsala the more trappean band occurs outside the calcareous band instead of inside, as we have seen it to the east. In the streams south of Choari several excellent contact sections are exposed. There is first a great thickness of soft green schist with a steady north-north-east dip, and over these comes the limestone,

with red and blue shaly slates, and quartzose sandstone. These rocks, here as elsewhere, exhibit much local disturbance, though with an average underlie to north-north-east; the passage from them into the siliceous schists, alternating with porphyritic gneiss, is badly seen along the path. From about three miles north of Choari to where the gorges on the north of the ridge open into the valley of the Ravee, near Chumba, there is an unbroken section of more or less granitoid and gneissose rocks, in every portion of which a north-easterly underlie can be easily distinguished. Along the border of the valley of the Ravee there is a narrow skirting of fine mica-schist over the gneissose series. The section is then covered by the valley deposits, as far as the Ravee, at Chumba, where we find dark, and light-gray, thinly-bedded, sub-schistose slates, with courses of thin quartzose grits, having a steady dip of 70° to north-east;—a group of rocks much resembling the series already spoken of as the Simla slates or Infra-Blini series. I have little doubt that these are the rocks that I noticed to the north of the ridge from the Murrumghattee, over Dhurmsala.

Termination of granitoid band at Dalhousie.

In this section of the Dhaoladhar, by the Choari pass south of Chumba, we have just seen a band, about eight miles broad, of granitoid and gneissose rocks, the same as those we have traced for many miles from the south-east, and extending to an unknown distance in the same direction; being in about the lineal continuation of the great chain of snowy peaks beyond the Sutlej, which, we know, have similar geological characters. Yet within ten miles to the west of this Choari section the whole mass has disappeared. The station of Dalhousie stands at the very extremity of this band of crystalloid rocks, forming the core of the Dhaoladhar. The mode of disappearance is important; it corresponds very exactly with analogous features noticed elsewhere. On Dainkhund, the summit, nine thousand feet high, to the east of Dalhousie, the granitoid gneiss shows a general easterly underlie. Low down on the northern spur from Dainkhund, along the road from Chumba to the plains, the last remnant of the central gneissose band is crossed. The slates of the Chumba valley are in contact with it at about the bifurcation of the lateral gorge, south of Mila, having maintained a steady average north-easterly dip; the schistose gneiss nearest to the junction shows a dip of 50° to the east-north-east, which is continued on the spur about Dhar; down this spur the band contracts, and to all appearance, as seen from this place, it becomes extinct before reaching the Ravee, on the right bank of which there seems to be a continuous section of thin-bedded crumbling strata. On the short secondary spur over Gurwal the schistose slates come in, on the west of the granitoid band,—fine-grained, gritty, sub-schistose, greenish gray slates, having a steady dip of about 60° to the east-south-east, towards the centre of the ridge, the strike being parallel to what is here the

direction of the boundary. The open valley of Rampur is excavated in these slates. In Dalhousie the junction occurs at the gap between the Potrain and the Perasana hills ; it is about the most westerly point to which the granitoid band reaches. The dip in both rocks at this spot is much lower than usual ; both are, moreover, a good deal decomposed, so that their contact here is not well seen. I obtained a better section of the contact in the angle of the gorge between Dalhousie and the "slate" quarries. For about fifty feet from the granite the schists exhibit a very marked increase in induration, acquiring a close-grained, crystalloid texture. Near the contact, irregular small veins of the granitoid rock are included in this hard contact-rock, yet the junction with the main mass is perfectly sharp, indicating no approach to an amalgamation of their ingredients. The inner rock here has its most granite-like aspect, yet the foliation and rough stratification show conformability to the schist series, the dip in both being about 50° to east 15° north. In this gorge, and again in that of the Naina, the indications of the general super-position of the crystalloid rocks on the schistose series is as plain as in any instances already noticed ; the curve of the contact is turned well up the gorges.

Schist band.

In the Dalhousie sections we find particularly well marked a feature of which indications may have been noticed elsewhere ; namely, the occurrence of a band of rocks more or less slaty, or more or less schistose between the central granitoid mass and the band of limestone and shaly slates. In the Choari section this was very obscure ; in the Dhurmsala section it was more defined. In the Dalhousie section we have just seen how well marked the inner of the two boundaries can be. As an instance of how capricious the metamorphic action has been in this transition zone, I may notice a thin band of strata that is seen on the road side near the "slate" quarries, nearly on the strike of the slates, and within fifty yards of the quasi-granite ; they are beds of compact, splintery, very earthy limestone, or rather calcareous clay, very like some of the lower-Krol beds ; yet such a rock is one which, according to generally received notions of metamorphic agency, ought to exhibit more change than the coarser siliceous rocks among which it occurs ; containing, as it does, in itself such elements of chemical re-action. In the descending section to the west of Dalhousie the schistose characters become again more and more developed ; at Bunketra we find decided mica-schists. On Dulog ridge these overlie a thick mass of gneissose schist, having a steady dip of 12° to east 10° south. An ore of iron has been largely worked in this gneiss rock ; it occurs as irregular strings and masses, principally of magnetic oxyde. This gneiss band of Dulog is underlaid by more mica-schist, which, in the valley and along the gaps, occurs in abrupt junction with the limestone and shaly slates. I have no observation to show how this metamorphic zone behaves to the north and west ; whether it also thins out, like the central run of granitic rocks, or whether it continues beyond the Ravee into the Jummoo territories. The former seems the more likely.

Krol band.

Continuing, in the same direction, the section from the point of the Dhaoladhar ridge to the Ravee, we find the uppermost band of the Himalayan rocks as well marked as we have seen the others to be. The limestone, with shaly slates, both red and blackish, some quartzite-sandstones, and a little trap-rock, is three times repeated on the spur beyond Bugrar, an east-south-east dip prevailing. This is the last I have seen of the group that I have conjectured to represent the Krol beds. The final steep fall of the hill into the gorge of the Ravee, to the contact of the Sub-Himalayan

series, is entirely in trappean rocks. I could have wished to have devoted a much longer time to the study of this most interesting region, but my observations of it were necessarily as hasty as any that I could make of these older rocks. It is to be hoped that some of the many visitors to the charming sanitarium of Dalhousie will tell us more about the geology of the neighbourhood.

East of Chor.

I have still to give a brief notice of the Lower Himalayan rocks lying east of the Chor. In proceeding south from Deobun, along the ridge of Bairat or down the valley of the Omlao to the Jumna, the rocks are found very variously disturbed, but with a prevailing north-east dip, and on the whole the section seems a descending one; there is a great variety of slates, grits and sandstones, with even some limestones, but no rock that I could identify from passing observation. The sections already noticed to the west of the Tons lead us to conjecture that this region of the Omlao is one of moderate special elevation, involving irregular dislocation and denudation, by which the winding courses of the two great rivers may have been predetermined to their confluence below Kalsi. Still even here we find evidence of a narrow, fringing zone of less upheaval, although it too partook of the local transverse elevation: the Blini conglomerate-grit is largely developed along the Taru ridge over the Tons, west of Kalsi.

Masuri ridge.

Along the Masuri ridge, from Budraj on the west to Surkunda on the east, a distance of about twenty-five miles in a nearly east and west direction, we can, with much probability, identify the rocks with those of the Krol. Budraj hill is composed of green and purple slates, and grits with some quartzitic sandstone. They are traversed at all points by greenstones: the dip is very irregular, but is mostly north-eastwards. On the next summit, the extreme west end of Masuri station, clear sandy and cherty limestones have a high dip to the north-north-east. An anticlinal line traverses the ridge at a very small angle of obliquity: on the Abbey hill the same limestones

have an opposite dip; while on the Camel's Back hill the northerly underlie again prevails. Immediately under this limestone a black shale is almost everywhere conspicuous, and here, as in the neighbourhood of Subathu, it has often raised expectations of the discovery of coal. The whole series must be greatly contorted, for we find crushed black slate repeatedly on the ascent to Masuri, from the very base at Rajpur. Landour summit is composed of a variety of hard fine grits, thick micaceous sandstones, and strong sandy limestone, with a general dip to the north-north-east. At the gap below the hospital on the east, a synclinal bend brings in the same beds, with a south-south-westerly dip. Across the spurs to the north the strong bedded clear limestone band crops out from under these beds, and strike into the ridge to form Tuppobun summit, with still a south-south-westerly dip. The same strike, oblique to the direction of the ridge, brings in the slates again under the limestone; there are pinkish and greenish, as well as dark varieties. Under these, at the turn up to the Sakunda summit, the Blini limestone and its conglomerate are typically seen. Next the limestone the base of the conglomerate is shaly, it rapidly becomes gritty, then sandy, and so in a manner passes into the coarse clear sandstones on which it rests, and which are throughout more or less conglomeritic. These massive sandstones form the summit of Sakunda; at the peak itself they seem to turn over to the north-north-east. A short way below the road on the southern spur from Sakunda, the Blini group again shows, in front of the sandstone. Thus, throughout this whole range, the strike is very steady, becoming towards the eastward gradually nearer to a north-west, south-east one.

Section in the Hewnulgur.

After the observation just made, one is surprised, on descending into the valley of the Hewnulgur, to find a totally different state of things. Even above Pugali, well up on the flanks of the ridge, blue slates are dipping steadily at 50° to the north-west. With local exceptions, this north-westerly and westerly dip is steady for a

long way down the valley, in slates, sandstones, and sub-schistose rocks. Yet, at a little below Batouin, strong bedded, clear limestones come in with the former south-westerly underlie, and it is here in the exact continuation of the strike of the rock on Tuppobun peak. These facts point strongly to extensive unconformability between these rocks, yet the contortions that all have undergone are so great that it will be very difficult to settle this question satisfactorily. South of this limestone the dip is again greatly confused, being both north and east, in blue glossy slates, red and gray slaty micaceous grits, and coarsish pink sandstone. Below the confluence of the stream from Thaline with the Hewnulgur, there is an east and west anticlinal line well marked in this sandstone; the valley soon opens out in the crumbling blue slates and grits; at first they show the same strike as the sandstone, but before long they dip to the north-east and south-south-east; in fact they present no single order of disturbance. Just above the confluence of the Hewnulgur and the Ganges, streaked slates underlie to the south-west, and on the right bank of the Ganges they are overlaid by typical Blini limestone, and its slaty conglomerate. Not far down the river strong clear limestone, calcareous sandstone, and black shale are crushed together along a steady north-west, south-east strike. At the southerly bend of the river above Tuppobun the fine earthy compact beds of lower-Krol type are greatly twisted together; but through all a steady, general north-west and south-east strike is traceable.

East of Ganges.

Of the hills east of the Ganges I have seen very little. The Blini conglomerate shows abundantly at the base of Merhal hill. The principal rocks of this hill are pink and greenish slates; sandstones appear near the top, and the summit is of strong-bedded limestone, underlying to the north-east, but also subject to local irregularities of disturbance. About two miles south of the summit there is an abrupt depression in the ridge. The slope is of decomposing ferruginous slate and sandstone, and in the depression, which is about half a mile wide, we find the remnant of the

Subathu group, as already mentioned. On the south, about Kothar village, the nummulitic rocks are in contact with schistose slates. Here, and down the upper valley of the Tal, these rocks strike north-north-west. In the gorge cut by the Tal through the north and south ridge, there is found a rock which is for the present unique in a very important respect: it is the only fossiliferous rock that I have met with or heard of *(well authenticated)* in all these Lower Himalayan rocks. The fossils are indeed very obscure, fragmentary impressions of bivalve mollusca, but they are undoubted organic remains. The rock is a sandy siliceous limestone, in thick beds; but the whole is not more than twenty or thirty feet in thickness. The band occurs twice in this short gorge, being repeated by a sharp anticlinal flexure. The beds associated with this limestone are pink, gray, and black shaly slates, the latter being often crushed, highly carbonaceous, ferruginous, and sulphureous, after the manner of the Infra-Krol rock. On the whole, the group suggests this connection, but in a degree far from conclusive. The same beds form the ridge for some way to the south-east, to the villages Kimsar and Ambwala.

Fossils.

Along the flank of the outermost ridge, north of the Kota dun, I have noticed, among the glossy, dark, clay slates, abundant debris of a slaty conglomerate exactly like the Blini rock.

Kota dun.

The section through Naini Tal and Almorah presents some analogies to the Simla section. The ridge of Naini Tal is a great synclinal range, with many local fractures and contortions, just like its type, the Krol range. I believe, too, that the rocks are representative. The great limestone that forms many of the summits to the south of Naini Tal is very similar to the Krol limestone; and the pink, greenish, and dark gray shaly slates associated with it show affinities to the same group. The Samkhet valley to the north of

Naini Tal and Almorah.

Naini Tal corresponds structurally to Kundah Ghât. But here it is a line of extensive trappean intrusion. To the north of this line it seems probable a great upthrow has taken place, or else the rocks are so altered as to be no longer recognizable; they are thorough metamorphic rocks. Along the heights of Sunthala and Ghagur, immediately above the Samkhet valley, the schists are gneissose.

In this schist series we are again met by the fact of a remarkable decrease in the disturbance of the strata, as compared with that of the outermost belt of rocks. There is a very general inclination to between north and east, and at angles averaging between 30° and 50°. From the few observations I made on the granitic and gneissose rocks south of Almorah, there seems to me to be considerable analogy in their mode of occurrence to that of the same class of rocks to the north-west. Here indeed the rock is lithologically truly crystalline, a complete granite, but in its mode of insertion among the schists there is the same pseudo-conformability, as described on the Chor and elsewhere. The rocks to the north of it, and apparently resting on it, are even less metamorphic and less disturbed than those to the south.

Igneous rocks. Their age.

As far as I can assert upon direct observation, the only igneous rocks within our district occur among the older strata, and are thus presumably pre-nummulitic. I am inclined, however, to accept general evidence against this supposition. The facts of the distribution of the intrusive rocks are peculiar and most interesting. The occurrence of trap in the metamorphic rocks seems to be rare, yet it is very frequent in what we have presumed to be strata of more recent date, in the Krol group and the subjacent slaty rocks. This peculiarity suggests that the trap may be cotemporaneous in these deposits, and may have been derived from some distant source. But we find no confirmation of this opinion; the distribution of the trap in these deposits is anything but constant; it is moreover manifestly intrusive

and connected with the disturbances of the sedimentary rocks. Over a large area in the typical region of the Krol rocks I found no trace of trap in these strata; this is one of the many peculiarities for which this main watershed region is remarkable, as already pointed out. It will be seen in the next chapter that the nummulitic rocks, the Subathu group, have only been preserved in this very same region, so that the absence of trap in the Krol group here may account for its absence in the Subathu beds also. There is another strong argument in favour of the same view. I will show reason for conjecturing that the Krol group and the slates had not undergone very extensive disturbance prior to the deposition of the Subathu beds, and hence an additional probability that the trappean intrusions are also of more recent date. One of the few instances of the occurrences of trap in the vicinity of the nummulitic area is seen on the road side east of Saihutti, over the village of Tunsata; a vein of green-stone occurs there in the dark shaly slates underlying the limestone.

In regions of disturbance.

Trap rock is found most abundantly in those parts of the district which are regions of extensive disturbance. In the limestone region of the Sutlej valley, between Komarsin and Dihur, there is a typical instance of this, as compared with the less disturbed area of older slaty rocks to the south. The most continuous exhibition of trappean action is along the base of the Dhaoladhar, and stretching thence down to Suket; in this region we find also vesicular varieties of trap that I have not noticed elsewhere. As a rule, there is very little variety in the composition or texture of the intrusive rock; it is a dense basic greenstone, more or less compact or sub-crystalline; sometimes, in limestone rock, it is changed into a fine grained binary trap; good examples of this are to be seen in the Shali mountain. I have nowhere noticed highly felspathic, or siliceous varieties.

It is with much diffidence that I approach such a vexed question as that of *cleavage ;* more especially as I have little or nothing to say in the matter, for or against any of the proposed theories. The fact is, I have failed to observe any general phenomenon of the kind. This will surprise many, as it did myself. I make the statement, however, under correction, and in direct opposition to a recent assertion of the contrary by observers of some repute. In a paper already referred to, by the M.M. Schlagintweit, in Volume XXV. of the "Journal of the Asiatic Society, Bengal," p. 118, the following passage occurs: "It was observed a long time ago, that in the great mass of gray schists which must be traversed before reaching the central group of the Himalayas, a remarkable uniformity in the dip of apparent stratification prevails. Our observations have perfectly convinced us that this is no real stratification, but merely *cleavage,* produced, as is now generally assumed, by a great tension in the interior of the highly altered rocks." If the structure described in this passage can be called *cleavage,* I confess that I am utterly ignorant of the meaning of the term, as likewise of the term *stratification.* I could not refer to simpler examples of interstratified varieties of metamorphic rocks than occur along the section through Almorah—the one alluded to in the passage just quoted. Cleavage is however to be seen in the outer Himalayan rocks. The best instance I have observed of it is at Naini Tal: the slates quarried on the flanks of Chenur are true cleavage-slates. But even here the phenomenon is only partial; in many sections of slaty rocks at Naini Tal I failed to detect anything I could recognize as regular cleavage; and in the several places where it can be traced it does not maintain a constant direction. If originally it had a common direction, as may perhaps be presumed, subsequent disturbance has quite obliterated it. The slates used at Simla are easily recognized to be merely lamination slates. Again, the excellent roofing slates of Dhurmsala and Dalhousie,

Cleavage.

At Naini Tal.

At Simla and Dalhousie.

obtained from the metamorphic zone of the Dhaoladhar, do not exhibit the phenomenon of cleavage in an indisputable manner: the rock in question, it is true, is perfectly fissile; but more fine-grained argillaceous rocks interstratified with it exhibit no such tendency, as should be expected in the case of a true system of cleavage. Moreover, the slate itself seems to me to suggest the opinion that it is due to an exceptional form of foliation: it is a very fine siliceous rock, showing a delicate micaceous glaze on the surfaces along which it splits. These planes moreover coincide with that of bedding.

The discussion of the structural features of the Himalayan rocks, described in the foregoing pages, cannot be profitably undertaken until after we have examined the evidence regarding the Sub-Himalayan rocks. It is however already manifest how very limited and hypothetical any general argument must be until more is known of these older rocks, until some connection be established between them and the rocks of the central mountain regions. The Krol group has the strongest claim for interest, and offers at the same time the most hopeful prospect of discovery. A similarity has more than once been noticed between the slates of the Lower Himalaya, and the so-called azoic slates which underlie the palæozoic strata on the northern side of the snowy range; and the identity of the two has been surmised from this similarity. It is something gained, however small, to be able to point out a fair prospect of settling this question independently of fossil evidence. In the hills immediately across the Ravee north of Dalhousie, the limestones and slates on the south of the Dhaoladhar must come into contact with the rocks of the Chamba valley, and there can scarcely be much difficulty in discovering their relation to each other. I think, moreover, there is much probability that the Chamba slates can be traced continuously into connection with the unmetamorphic rocks of the Thibetan regions.

Probable connection, through Chamba, of the rocks on the north and south of the snowy range.

CHAPTER III.—*Sub-Himalayan Series—The Subathu Group.*

IT has been shown in the preceding Chapter that we cannot yet affirm, with any degree of certainty, to what age any of the stratified rocks of the lower Himalayan region belong,—from lowest Tertiary to oldest Palæozoic. The truly historical portion of the record begins with the Subathu Group. A glance at the map will show the limited extension of this group, which is the lowest member of the great Sub-Himalayan series. With two very local exceptions, to be specially noticed, it is limited to the region between the rivers Jumna and Sutlej, that region which we have already seen marked by peculiarities in the arrangement of the lower Himalayan rocks. I will defer the discussion of this actual limitation to the end of this Chapter, as being the result of phenomena subsequent to the deposition of the formation.

Position and extension.

The succession of deposits, which I have provisionally ranked under one name as the Subathu Group, exhibits a very considerable diversity of mineral characters. In the bottom portion we find almost exclusively the finest description of sediments; a yellowish brown silt may be taken as the characteristic rock.* In the succeeding portion of the formation, a gritty, lumpy, bright red clay is predominant: these clays are slightly gypsiferous. Fine grained, massive sandstones greatly preponderate in the upper part of the group. The united thickness of all can scarcely be less than 3,000 feet.

General composition.

There can be no doubt that this formation represents a very prolonged period of deposition, involving, as is shown by the change of composition, a very considerable alteration of conditions. Nevertheless, pending the collection and examination of

Considered as one group.

* I fail to recognize in the Subathu section the rocks spoken of by D'Archiac as "Marnes noires" and "psammite."

fossil evidence, I have left them as one group, for the following reasons:—*firstly*, the threefold characters I have noted in the sediment are perfectly transitional by interstratification, the change in the nature of the deposition being gradual, from what we may suppose to be tranquil deposition in moderately deep water to tranquil deposition in shallow water. There is scarcely even a small pebble to be found throughout the whole formation, as represented in this area. And, *secondly*, there is much evidence for the supposition that, in one direction at least, the limitation of the basin of deposition was the same for the lower as for the upper beds.

As a Sub-Himalayan group.

It will be shown, with much probability, that a period of most extensive denudation, consequent on considerable disturbances in this region of the Himalayan system, intervened before the deposition of the rocks which here follow next to the Subathu group. Yet I rank this group as the lowest of a series of formations, under the same general name *Sub-Himalayan*, because this group seems to have had an original limit of deposition approximately coincident with what has been ever since a limit of deposition, with what has been throughout a zone of disturbance connected with the Himalayan system of elevation, and with a zone of, what may *now* be emphatically called, Sub-Himalayan rocks. Great as the interval in time must have been between the deposition of the Subathu group and that of the succeeding groups of the series, at least in the eastern part of the district, we find in the upper portion of the Subathu rocks the very characters most distinctive of this great Tertiary series, as a whole; the massive clays and sandstones of Dugshai and Kasaoli being unmistakeable congeners of the rocks of the Nahun and the Sivâlik Hills.

Relations to Lower Himalayan rocks.

The three following statements express the general relations of the Sub-Himalayan rocks to those of the Lower Himalaya. *First*, the Subathu beds, the sub-group of undoubted nummulitic age, rest upon a deeply denuded surface

of the Lower Himalayan rocks. *Second*, the present boundary of the Subathu group seems to have been approximately its original limit of deposition. *Third*, the Lower Himalayan rocks had undergone comparatively little disturbance before the deposition of the Subathu group. In explaining these views I will adopt the supposition made in the preceding Chapter regarding the normal order of succession of the older strata.

Denuded surface of contact :

The best evidence for the three statements put forward in the last paragraph is found at the very station of Subathu. In the many outliers of the nummulitic beds on the north-east of Subathu (they are too numerous to be all represented in a map on so small a scale), and for the most part along the boundary of its main area, the Subathu group is found in contact with Infra-Krol and Infra-Blini strata. Still, contortion has so complicated the original relations of the two sets of rocks, that direct evidence to prove that the sequence between the two formations was not regular is very rarely met with. A brief consideration, however, even of a single case, leaves very little doubt in the matter. For instance, in the case of either of the outliers shown on the section of the Krol (Fig. 3), had the nummulitic beds been originally deposited upon an undenuded surface of the Krol group, the faulting necessary to account for their present relative position would be inconceivable,—long, narrow trough-faults with a throw of 2 or 3,000 feet on either side. The great number of such faults also, and their very close proximity, would add to the improbability of this mode of explanation. The argument is further borne out by the total absence of any direct evidence, such as the occasional appearance of the Krol rocks themselves in these troughs : of this appearance I have not discovered a single instance. Another strong argument against the idea of such faults would be their abrupt termination ; thus, within less than half a mile to the east of the two bands of nummulitic rocks in the valley of the upper Blini, we find

inferred from general condition of outliers;

on the Solun watershed no trace of this kind of disturbance. Without going beyond the negative evidence, as here pointed out, it seems to me there is no alternative but to suppose that, prior to the deposition of the nummulitic beds, the escarpments of the Krol and the Boj stood face to face pretty much as they do now, though at a much greater distance from each other, and that the deposition of the newer strata took place between them, upon a bottom of Infra-Krol rocks. The adoption of this supposition at once meets all the exigencies of the case.

obscurely supported by special sections; and

There are scores of sections to be seen in the numerous little ravines crossing the boundaries of the long, narrow, outlying bands of nummulitic rocks, but their character is wonderfully uniform. As an example of their type, I will detail the section of the main band near its termination in the Blini valley, at the confluence of the head waters, where the stream commences its longitudinal course. In following downwards the stream from the Boj, the carbonaceous slates, and thin grits of the Infra-Krol group, show increasing intensity of compression, maintaining however a steady north-westerly strike. Close to the junction with the nummulitic rocks the Blini limestone appears among these grits and slates: as is usual in such cases, and as might be anticipated, where a hard band is associated with more pliant beds, the two are greatly jumbled together. Within six feet of these contorted rocks, in the bed of the main river course, the red and gray marly nummulitic clays are vertical, and with the same direction of strike. The slate rocks come in again almost immediately on the northern bank, the distance from one junction to the other being about 100 feet,—the entire thickness of the nummulitic band at this place. At the contact on this side both rocks have a slight north-easterly underlie, being conformable, as far as can be seen in a low section, and thus, to this small extent, the older rock overlies the younger. The Blini limestone appears within about twenty feet of the junction; its bedding is not so broken up as on the other side

of the outlier, but it underlies to the south-west, showing that on this side also the beds are sharply folded together. Here we find the Blini conglomerate underlying the limestone. I have attempted to represent these facts in Fig. 3, page 24. Such sections as this are difficult to reconcile with the conditions I have supposed; though on so small a scale, and therefore, from my point of view, bringing us so close to the base of the younger rocks and to the original surface of contact, there is no recognizable bottom-rock of the upper group, no contact is seen that can be said to be original, and where one can be at all sure the actual juxtaposition is not produced by contortion and faulting. If this mode of explanation be once admitted it is difficult to fix the limits of its application.

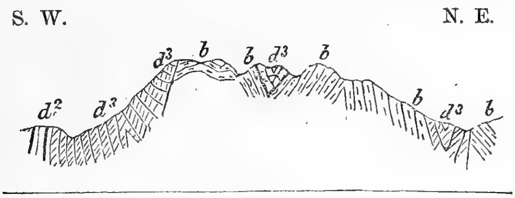
I know of only one section which promises to give conclusive evidence upon this question of junction. On the small patch of level ground (where barracks formerly stood), just north-east of the bazaar at Subathu, we find the red and gray, marly, nummulitic clays in more or less vertical bedding along a steady north-westerly strike. Sub-schistose slates rise on either side with an underlie towards the fossiliferous rocks. The junction is particularly well seen along the south-west edge. In contact with the slates there is a thick bed of a peculiar rock, an exceedingly fine clay, but indurated in a peculiar manner like semi-porcelain; it is also characterised by containing large grains of pisolitic iron oxide, which are sometimes present in great abundance. Along the steep descent into the gulley on the north-west, above the bifurcation of the stream, this contact can be followed to a considerable depth, and there is very approximate conformity throughout: the thin slates are occasionally wrinkled, but it seemed to me as if the same beds might be in contact all through. Before reaching the north-east branch streamlet the nummulitic beds cease;—the slates soon rise with a reverse dip, and at several points along the north-east boundary the same bottom bed

proved by the section at Subathu.

A bottom bed.

is found resting upon them, as on the other side. We have here the section of a synclinal fold displaying a true bottom rock of the Subathu group: it is shown in Fig. 9. The regularity and simplicity of this

FIG. 9.



Section through ridge at Subathu. *b.* Slates. *d.*³ Nummulitic beds.

little section is in strong contrast with the anomalous conditions that prevail elsewhere, as already described. Along the great bands of these nummulitic rocks in the valleys to the north-east, I have never observed this peculiar bottom-rock of Subathu; it is either concealed, or else never existed. This is the more remarkable since I have unmistakeably identified it on the north of the valleys in a somewhat analogous position to that at Subathu. High upon the south side of the Sairi hills, at the summit of one of the steep slopes where the road changes from the east to the west side of the ridge, one cannot fail to notice an unusual rock; it is the ferruginous pisolitic bottom clay of the nummulitic group; for a few yards below it, on the hill, there is a remnant seen of the red and gray calcareous clays, the same as occur with it at Subathu; I have found fossils in this locality, but the rocks are greatly crushed and obscured. The determination of whether or not this bottom-rock is common to the whole intervening area involves some interesting considerations of detail regarding the pre-nummulitic condition of the surface, and the process of formation of this group, I suggest it to the attention of future observers.

It will be recollected that in the second Chapter, page 54, I described the region of Subathu as one of more than usual obscurity among the Lower Himalayan rocks: in so far, therefore, as the evidence

depends upon this section at Subathu, doubt in the same degree must rest upon the proposition I am now attempting to establish. My impression, however, is that the slate rocks here in contact with the nummulitic strata belong to the Infra-Blini series. As long as this hesitation remains, sufficient weight must be given to the *general* argument for the pre-nummulitic denudation of the Krol group, based upon the evidence of the outlying bands in the valleys to the north-east of Subathu. That argument seems to me sufficiently strong to stand by itself.

A doubt.

The whole area but an outlier.

The conditions described for the small isolated or semi-isolated bands of nummulitic strata are applicable on a grand scale to the whole area of the Subathu group; it is itself, to some extent, contained in a great trough of depression or of folding; it is now almost insulated from all connection with succeeding deposits, upon a ledge of the older rocks;—along the whole of its south-west boundary there is scarcely a section in which the older rock does not appear beneath the nummulitic beds, thus forming the contact rock with the middle Sub-Himalayan group. This state is most evident in the north-western portion of the area: from the Sutlej to beyond the Ghumber there is a well defined ridge of limestone, underlaid by black shale, enclosing the nummulitic rocks on the west. It is not only along the boundary of the group that the underlying rocks appear: in more than one place of the eastern part of the region, in the deeply cut valleys, the black shales weather out from below the brown nummulitic clays; the best example I know of is in the valley of the Guggur, north of Morni. In these positions it is often difficult to distinguish between the two rocks; the best general test is the thin, sharp bedding, and frequent fine lamination of the Infra-Krol strata, as contrasted with the thick amorphous beds of the nummulitic clays. The non-appearance of the Krol beds themselves, in situations such as this, gives conclusive proof, if any were still needed, of the extensive removal of that group prior to the nummulitic period.

Having disposed of the first, I may now take up the second point of relation between the Subathu groups and the underlying rocks, namely, that the present north-eastern boundary of the group was approximately its original limit of deposition. That the nummulitic rocks are not now found more extensively covering the Lower Himalayan area gives but little reason for presuming that this condition did not once obtain. There is, however, a fact tending to suggest this, *viz.*, that not even a single outlier, beyond a certain well-defined line, has been found over so large an area of the Lower Himalayas; the contortion to which both series have been simultaneously subjected would assuredly have enfolded some of the upper strata, so as to be protected from subsequent denudation. We find better evidence in the variation of the nummulitic deposits themselves, that they had an abrupt limit at or about what is now their inner boundary. This might have been conjectured from the consideration of the facts already given. In the section described in the upper Blini, in what I presumed to be almost the base of the Subathu beds, I mentioned red clays as equally prominent with other varieties. In proceeding from that section westerly along the strike of the rocks, down the river, as the band of upper rock expands, we soon come upon massive sandstones interstratified with red clays and fossiliferous nummulitic clays, conditions strongly indicative of a higher part of the series. In the section at Subathu itself, among what are positively bottom rocks, the same characters have been noted. The comparison of these sections with those to the south-west leads to important conclusions.

A north-east limit of deposition.

Section at and north of Subathu.

In descending from Subathu by the Budi road, towards the south-west, into the valley of the Chota Ghumber, a fall of some 1,200 or 1,500 feet, the whole section is in what may be called the Subathu beds, that is, in the lowest

Section south of Subathu.

sub-division of the Subathu group, the rocks already so well known as the nummulitic rocks of Subathu. Through this entire section the strata are almost exclusively of the character peculiar to the base of the group, —dull greenish, yellow, and brown clays, sometimes calcareous, and with occasional layers of concretionary earthy limestone ; there are a few beds of grit, or even of fine, earthy, brown sandstone. I cannot assert that the whole section from Subathu to the Ghumber is a continuous descending succession ; it is not unlikely that towards the base some of the beds are repeated by contortion, for in the valley we soon come upon transition beds belonging to the middle of the group ; but still there must be a considerable thickness of beds, which are but feebly, if at all, represented in the little section north of the bazaar at Subathu. At the edge of the ridge, where the road begins to descend from the south-west corner of the parade ground, there is a very instructive contact-section. At first sight it seems quite at variance with the opinions I have adopted regarding the original relation of the two series of deposits (*vide* Fig. 9) : the nummulitic clays are inclined at a low angle to north-east, against what seems to be a fault-surface of the thin-bedded, gritty, sub-schistose slates ; to complete the contrast, these latter beds are much broken and contorted, and next the junction are inclined at a high angle towards the younger rocks. They are the same beds which in the section north of the bazaar underlie the nummulitic rocks in local conformability of dip. A little consideration will enable us to adapt these facts to the conditions I conceive to have existed during the deposition of the nummulitic strata, namely, that they were deposited against cliffs, on ledges, and in deeply cut bays of the old rocks. Indeed, I am inclined to assert, that no other supposition will reconcile the two sections. This ridge of the old rocks at Subathu formed an eminence on the nummulitic sea-bottom ; the area to the north of it was also at that time, probably to a greater extent than now, raised above the area

Comparison of the two.

to the south-west, and on this account we find at Subathu and north of it, only a partial representation of the bottom rocks, a step, as it were, in the conditions which excluded the whole series from the region of the Lower Himalaya. I need hardly point out that lateral compression might readily produce the result represented in Fig. 9, at the edge of the Subathu ridge, between beds that had been approximately parallel. I do not pretend to say that no slipping has occurred along this junction; it were improbable to suppose that it had not; and we even see positive evidence of it in the slightly streaked and polished surface of contact; but that it was inconsiderable is strongly suggested by the fact, that the nummulitic beds here, and in the section beyond the bazaar, are about on the same geological horizon as well as at the same actual level; both are about the termination of the fine silty, calcareous, fossiliferous deposits.

On the sections at and about Subathu, almost the entire evidence relating to the geological history of these nummulitic rocks depends. The removal of the Krol group from the area over which we now find the nummulitic outliers is peculiar to this locality: elsewhere, we find difficulty even in applying the mode of interpretation suggested by those outliers.

Exceptional character of the boundary at Subathu.

For example, towards its south-east end, the Subathu ridge passes along the side of the Boj; it is in fact so united to the latter as to form but one mountain with it, and the peak of the Boj rises but a few hundred feet higher than the sandstone ridge, from which it is separated only by a very shallow depression. The junction here gives one forcibly the impression of its being a great fault-line. The section is admirably exposed in the tunnel through the south-east continuation of the Subathu ridge, where it has again separated from the Boj. In Fig. 3 the section is taken across the summits, but the features are the same as at the tunnel and along the ridge: the black shales rise with a high dip from under the Krol limestone; in the depression they form a sharp anticlinal, thus

dipping at a high angle towards the sandstone ridge; the junction occurs at a short distance below the crest of the ridge on the north-east. All along the south-west face of the ridge, from Subathu to its termination east of the tunnel, the strong sandstones and red clays have a high dip inwards; along the centre there is a synclinal bend producing a fractured upturn of the beds towards the plane of junction. Thus on both sides every feature of the case is suggestive of a great fault with an upthrow to the north-east, yet if there be any force in the argument based on the sections of Subathu, such is not the case to any extent. The relative position of the beds in contact on the Boj are about what I suppose them to have been originally: on both sides of the junction the beds are about 1,500 to 1,800 feet higher in their respective series than their representatives at Subathu: and I may notice, though it does not materially affect the question, that this is about the difference of level of the two localities. Again, to the east, in the connecting ridge at the head of the Jalar valley, there is a section of the junction precisely like that I have just described, while in the low ground on both sides the soft bottom beds form the contact, which is always very obscure in such positions. Similarly to the north-west of Subathu the junction occurs in low ground, and in the softer beds, so that it is greatly concealed.

Contrast of rocks along inner and outer boundaries.

There is another step in the same line of argument. *All* the nummulitic beds about Subathu may be described as marginal and mixed when compared with their equivalents a few miles more to the south-west along the outer boundary, at least this seems to me a plausible inference from facts. The section seen in the Sursulla, two miles east of Kalka, gives a good instance of this contrast. On the north of the boundary of the Subathu group with the succeeding band of the Sub-Himalayan series, the dark brown nummulitic clay is the only rock exposed for more than quarter of a mile. The section is not unbroken, but the clay shows at intervals, in some places of several hundred feet in

thickness; it is greatly crushed, and has sometimes a quasi-metamorphic aspect. The same beds are probably repeated by flexures, but, making allowance for this, there is a greater display of the unmixed deposits than we find anywhere along the inner boundary. In this section, moreover, there is no semblance of transition into the upper members of the groups; the change is abrupt from crushed brown silts to bright red, coarse clay, and sandstones. This contact of the brown and the red rocks in the Sursulla, though roughly conformable, might easily admit of the supposition of shifting, and so of the concealment of a small band of transition; still we find the same general features prevail all along this outer limit of the formation. In the hills and valleys east of Morni the same brown, crumbling clay is largely exposed, and there is but little evidence for its transitional interstratification with the red rocks. These facts add weight to the inference which we may draw from the general contrast of the upper and lower deposits, as to the partial independence of the nummulitic strata proper; but they cannot negative the equally distinct facts in evidence of a transition. I do not believe that the interstratification along the zone of the inner boundary is due to a re-arrangement of the true nummulitic deposits. The contrast of the two sections may be explained by the more local character of the upper deposits, and by supposing them to have encroached from the north-east upon the finer sediments. This decided and important contrast is the more remarkable when we recollect that at the outer edge the whole formation is still seen, and that the thickness is not in any decided manner increased; there is little to suggest the rapidly deepening bottom of an open sea.

Fossil evidence of vicinity of land.

In the topmost beds of the Subathu group we find evidence strongly corroborative of the view I have been advocating as to the original limitation of deposition in this vicinity. At Kasaoli and elsewhere, in the youngest rocks of this area, we find abundant remains of land plants,—of trees and shrubs, which

must have grown in the immediate neighbourhood, probably on islands of the Krol rocks which had become inliers in the nummulitic deposits, and on the slopes of the land which I suppose to have existed to the north-east of this area from before the commencement of these deposits, and upon which land, in a somewhat remodelled condition, the fauna of the Sivâlik period lived long subsequently.*

Pre-nummulitic disturbance.

In each of the foregoing arguments upon the relations of the Subathu group to the rocks of the Lower Himalayas, the Subathu section has been brought to notice, and incidental mention was then made of the relation to which I wish now to draw attention, namely, the phenomena of disturbance as affecting these contiguous formations. The fact of such extensive denudation having affected the older rocks prior to the nummulitic period, implies that these rocks had also undergone disturbance, and it is of importance to be able to indicate the nature of that disturbance: *it was in no sensible degree the disturbance which produces contortion or flexure of strata.* There is *primâ facie* evidence for this statement in the fact, that the Subathu group exhibits quite as much contortion as do the Krol and subjacent groups, and that the manner of flexure is the same in both ; there are the same variations in general strike in one as in the other. The only direct corroborative evidence I can add to this general observation is, once more, derived from our Subathu section,—though small, it is not to be despised. The slate rocks at Subathu must have been approximately horizontal when the nummulitic clays were deposited upon them ; both follow the same synclinal fold.

Not contortion.

Elevation of Lower Himalayan area.

If the views that have now been explained be accepted, they offer some means of forming an opinion regarding the nature of pre-nummulitic elevation. By extending to the north-west and south-east the fact of the original limitation of the

* At the end of this Chapter will be found a notice of the plants and the other few fossils obtained by me from the Subathu group.

nummulitic deposits, as seen in the less disturbed section of Subathu, we can infer that the elevation of the area to the north-east, by which the nummulitic deposits were restricted, corresponded approximately in outline to the actual area of the Lower Himalaya, and that, therefore, the formation of the mountain zones, as we now see them, is not the result of one upheaval of the crust subsequent to the deposition of the Sub-Himalayan rocks. The small remnant of the Subathu beds, which occurs east of the Ganges, after a blank of sixty miles, is exactly in the line of continuation of the main area, on the outskirts of the Lower Himalaya. In the other direction, before the Subathu group disappears beneath the succeeding formations, beyond the Sutlej, it has bent round with the curve of the boundary of the Lower Himalaya. We are thus led to conjecture that the pre-nummulitic elevation was effected on the same lines, so to speak, as those which now mark the Himalayan mountain system. Another fact of some interest, and which supports the same view, is this: the range of the Krol rocks to the south-east of Solun is well outside the strike of the rocks in the outlying bands of the Subathu group; yet I never found a trace of this latter group among the rocks of the limestone range. To the north-west, however, on the range of limestone, north of Erki, and which, it will be recollected, I regard provisionally as the representatives of the Krol rocks, the nummulitic clays are easily detected; there is a well-marked band of them in the depression of the ridge, by the village of Kularun.

Subathu group east of Ganges.

From what we have seen of the nummulitic group of Subathu, one would not perhaps expect *à priori* to find its characters persistent over a large area. Its thickness no doubt is considerable, but it has been shown with some probability that its conditions of formation were rather confined and local. This expectation is to some extent confirmed; we do know that these nummulitic deposits differ much from nummulitic strata in an analogous position in Eastern Bengal, and that they altogether differ from those of the

Salt-range far to the north-west. Yet we will see that the peculiar deposits of Subathu once ranged far beyond the comparatively small area with which we have been engaged. This area terminates abruptly some miles to the west of the Jumna, but about sixty miles off just east of the Ganges a remnant again appears. It differs in no respect from what we have seen at Subathu,—pale, greenish brown, and red clays, with concretionary layers of earthy fossiliferous limestone. The locality is just opposite Riki-Kase, in a depression a short way to the south of Merhal summit, on the ridge which runs nearly parallel to the Ganges for about half the width of the dun. The depression is caused by the more easy denudation of the nummulitic band, which is about half a mile wide. I have already noticed the position of this outlier as being approximately in the continuation of the east end of the main area west of the Jumna, and irrespective of the deep re-entering boundary of the newer deposits in the valley of Dehra. The nummulitic beds here, as elsewhere, exhibit the same features of disturbance as the underlying strata, all being greatly contorted. The Blini group occurs about the base of Merhal, and the other rocks of the ridge show affinities to the Krol and Infra-Krol groups. I cannot say how far this band may continue to the east: this is the only locality in which rocks of this age have been observed by me within the districts of Kumaon and Ghurwal. I have heard of but one other case of their occurrence, and this perhaps requires confirmation. In one of their progress reports to the Government of India (Jour. As. Soc., Ben., Vol. XXV., p. 118), the M.M. Schlagintweit announce the discovery "in the clay-slates in the neighbourhood of Naini Tal, of numerous foraminifera evidently identical with those which accompany the Eocene nummulitic formation." Accepting the statement, it has occurred to me that they may have hit upon some small outlying band of the Subathu beds; it is sometimes very difficult indeed to distinguish these small bands from the rocks in which they are folded (see, for instance, the road section from Bil to the top of the Sairi hills). That

none of the careful observers who have also searched the rocks at Naini Tal should have found similar remains makes such a contingency the more likely. It is impossible in the case of such distinguished observers as the brothers Schlagintweit to suppose them deceived by the pseudo-fossiliferous appearance so common in the limestone at Naini Tal as elsewhere; the word 'clay-slate' is ambiguous in the above quotation; it may only mean the clay-slate series, and thus include the limestone.

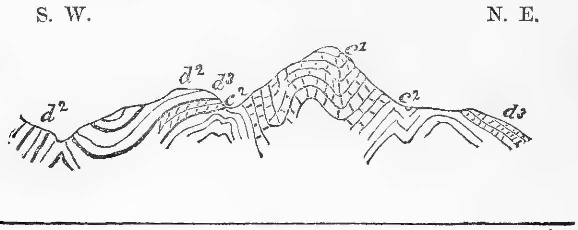
Subathu group south of Kashmir.

I have spoken of the Sutlej as the north-western limit of the special region of the Subathu group. This is not strictly the case. The nummulitic beds are well seen on both banks of the Sutlej at Dihur, and they extend for a short distance in the hills to the north, but they disappear long before they reach the Beas, in a manner to be presently described, and do not show again to the east of the Ravee. However, during a short trip I made to the Upper Punjab in 1859-60, I had the satisfaction of recognising the Subathu group in the hills south of the Kashmir valley, and beyond the Jhelum in Huzara.* The brown crumbling clay with earthy lenticuar limestone abundantly charged with fossils, and surmounted by deep purple clays with massive purplish sandstone, are as typical as in the valleys south of Subathu. The whole are found too, having the same kind of relation to underlying rocks which have a strong similarity to the Krol group. At Dundelee, three miles north of Kotlee, on the east of the Poonch valley in the Kashmir territory, one of the sections to which I allude occurs. A rugged ridge of hard blue limestone protrudes through hills of massive red sandstone and clays. The strike in both is very steady to east 35° south. The limestone strata are vertical and closely contorted; on both flanks of the limestone ridge we find the nummulitic clays cropping out from beneath the red rocks; on both sides, moreover, we find, beneath the nummulitic clays, thin carbona-

* Some years ago Dr. Fleming found nummulitic fossils in this district.

ceous slaty shales. The strings of anthracite which occur in these slaty shales at Dundelee were the object of my visit. Both the clays and the slates are greatly contorted ; but, as well as one could judge, they observe approximate parallelism in contortion. Fig. 10 represents roughly

FIG. 10.



Section at Dundelee, Poonch valley. $c.^1$ Krol group. $c.^2$ Infra-Krol. *d.* Subathu group.

the section at Dundelee. I was so struck by the analogy of the section with what I had seen in the Subathu region, that in spite of appearances, and, as I had not time to examine the ground more closely, I adopted the opinion that the carbonaceous shales were originally overlaid by the limestone band, which I took to represent the Krol group ; the identification is of the same vague kind as that made for the rocks in the valleys of the Sutlej and the Beas (*vide* Chapter 2) ; I could find no fossils in the clear limestones of the ridge. It should be noticed that the steady general strike of the rocks at Dundelee is remarkably constant towards the direction of Himalayan elevation.

Subathu group in Huzara.

The tract of mountains intervening between the Poonch and Murree, which is the great sanitarium of the Upper Punjab, is occupied by the Sub-Himalayan series. But in the region of the Jhelum valley a total change takes place in the system of disturbance. The well defined ridges about Murree have a steady north-east south-west strike, which is also that of the strata. So far, however, no new rock is introduced ; Murree is built upon a ridge of purple clays and hard sandstones ; the ridge to the north-west of it, a continuation of a lofty mountain-mass of Mochipoora, is of clear blue limestone. In the intervening valley, we find brown and variegated

nummulitic clays, and in the more deeply cut sections below Tret, about Shah Durrah, carbonaceous, sulphureous, gypseous, efflorescing shales are exposed, I presume, representing the Infra-Krol band.

Compared with the Salt-Range deposits.

The identification of the Subathu group, in its characteristic form, at such a distance, adds greatly to its importance, and it is of particular interest in this more northerly locality, on account of its comparative proximity to the nummulitic rocks of the Salt-Range, and of the contrasting conditions of the two deposits. There is no similarity between them as rock-groups; and there is no trace in the Salt-Range of the great thickness of hard sandstones and red clays, which we have seen to be constant companions of, and to be connected by interstratification with, the true nummulitic beds of Subathu, and which are so largely developed in the Murree district. The fact of the two thus disappearing together is an additional link between them. In the Salt-Range the massive unconsolidated mammaliferous clays and sands of the upper Sub-Himalayan groups rest upon a denuded surface of the clear, highly fossiliferous, nummulitic limestone. The simplest conjecture to form upon these imperfect data is, that the nummulitic limestone of the Salt-Range is the open sea contemporary of the Subathu group, and that the great clay and sand deposits which at first alternated with, and finally covered up, the nummulitic deposits along the Sub-Himalayan region, never reached so far as the Salt-Range. The comparison of the few fossils that have been described from the two deposits partially bears out the conjecture just made. In the work of M.M. D'Archiac and Haime there are forty-four species described from the Salt-Range, and the same number from the Subathu beds; *not one is common to the two localities,* a fact throwing some doubt upon the contemporaneity of the groups. In respect however of *habitat,* the species of Subathu are uniformly of shallow water forms as compared with those of the Salt-Range. The great difference in the nature of the sediments in the two localities leaves it possible for

the great specific difference of the fossils to be compatible with contemporaneity.*

The subject I will now bring forward is of great theoretical interest, as bearing upon the general problem of the structure of the mountain region: it is, the relation of the Subathu group to the succeeding member of the Sub-Himalayan series. Orographically the area of the Subathu group belongs to the Lower Himalayan region, not to the characteristic Sub-Himalayan zone. To the east of the Sutlej the inner boundary of the Nahun group is the most steady and most remarkable feature that occurs: it bears in all the sections the appearance of a gigantic fault, and it is of the utmost importance to obtain a true idea as to its real nature. In looking at the map the feature perhaps most readily noticed is the partial extension of the Subathu group as compared to that of the others. To the practised eye a closer inspection will show, that on the north-west this limitation is due to overlap by the younger rocks, while, to the south-east, it is produced by a very different cause, namely,

Relation of Nahun and Subathu groups.

Apparently a great fault-junction.

* In connection with these Punjab sections there is a suggestion to be noticed relating to the Krol rocks as much as to the nummulitic group. In the Murree section I noticed one new feature. In the nummulitic zone there occurs a considerable amount of clear blue limestone not distinguishable from that of Mochipoora, and in which nummulites are easily detected. The rocks just west of Tret bungalow are of this limestone; and again at the place called Clifden, near Murree, it is well seen. There would be nothing whatever forced in supposing this to be only a local development of limestone among the true Subathu beds, for even at Subathu we find occasionally bands of pure blue limestone among the clays. But there seems to be a remote possibility of this limestone being fully identified with the great mass of Mochipoora, and of Dundelee, and hence of the Krol; in which case the deeply denuded unconformability, which I have established between the Subathu beds and Krol group, would prove to be only a break in the nummulitic period. However improbable such a result may seem to be, I am induced to notice the fact in this connection, on account of the suggested reference of the Lower Himalayan slates and limestones of Naini Tal to the nummulitic period, as mentioned in page 88. Should such prove to be the case, the limestone of the Salt-Range probably belongs to this lower nummulitic formation; and under this arrangement the Salt-Range coal would correspond to the Infra-Krol carbonaceous deposits of the Lower Himalaya.

by the upheaval of the Subathu group, and its consequent removal from off the underlying rocks. It is with the time of this upheaval that we are now principally concerned.

Somewhat greater disturbance of the lower group.

In comparing the states of disturbance of the rocks of the Nahun and Subathu groups, the same general remark may be made as in the case of the latter and the Himalayan rocks; no marked contrast can be drawn in either case; yet, between the two Sub-Himalayan groups a slight difference is, I think, noticeable; it may be said that we nowhere find the strata of the Subathu group so little disturbed as we sometimes do those of the Nahun, as, for instance, at Nahun itself. It is however upon disturbance in *kind* rather than in *degree* that I wish to insist.

No outliers of the upper group;

Among rocks so essentially alike as are the several members of the Sub-Himalayan series it is particularly hazardous to assert, upon negative evidence, that the newer members had never overlaid the older ones at any place; remnants might well be present without being noticed, yet, I am inclined to think that the Subathu group here has never been so overlaid. The Kasaoli beds form a really distinctive capping to the Subathu group, and I have never detected any younger rock within the Subathu area.*

* Those who may have examined the account given by D'Archiac of the section at Subathu, will be surprised at the statement in the text, that no younger rocks occur within the area of the Subathu group. At page 176 of the "Groupe nummulitique de l'Inde" repeated mention is made of sands and conglomerates, with large mammalian remains undistinguishable from those of the Sivâliks, resting conformably upon the nummulitic strata at Subathu; the author remarking upon the interest of this apparent intimate connection between two groups so distinctly characterised. It is fortunate the error is on so large a scale, for few will be disposed to question my assurance that no such rocks occur at Subathu; unless indeed, after the similar failure to confirm Lieutenant Durand's discoveries at Nahun, as noticed in the first Chapter, p. 15, one may be disposed to consider me fossil-blind. In this case, however, I have succeeded in obtaining an explanation from the discoverer himself. Finding no allusion to any such deposits at Subathu in the original paper by Captain Vicary (Jour. Geol. Soc., London, Vol. IX., p. 70, 1853)—the only authority quoted by M. D'Archiac—I wrote to that gentleman and received an immediate reply, expressing astonishment at the statement referred to him: "I cannot think how D'Archiac's mistake originated; I do not understand French, and never

It is of more significance for the point I wish now to establish to mention that I have never seen any trace of the Kasaoli beds weathering out from beneath the newer rocks to the south, where these have been much disturbed and denuded. We do find, among the strata of the middle band, individual rocks undistinguishable from some in the Subathu group,—such are some hard purple sandstones and clays that may be seen south of the nummulitic beds at Kalka, or on the road between Kudi and Budi; yet if the connected sections be compared this surmise is not confirmed, no one would, I think, in the section of the Sursula identify any portion of the band of rocks, south of the nummulitic clays, with any to the north of them, although individual rocks may be undistinguishable. The important question to be settled is,—should we *at any depth* find the Subathu beds beneath those of the Nahun group? *i. e.*, were these latter deposited upon a surface of the former, whether denuded or not, their actual relative positions, as seen at the surface, being due to a great fault; or, is the actual boundary a line carved originally by denudation (along a coast) out of the upraised area of the Subathu rocks, and along which the Nahun beds were deposited? I am strongly in favour of the latter view; it does not preclude the supposition of subsequent shifting along this line.

or inliers of the lower one.

Statement of the case.

However or whenever the present relative elevation of the Subathu over the Nahun groups was produced, it was unequal,—vanishing to the

detected it until I got your letter. I surely never said that Subathu was built upon anything bearing the most remote likeness to conglomerates. I never said or wrote anything of the kind, and never alluded to conglomerates at all." He further explains that Allea Bukhan, a locality given by D'Archiac as in the neighbourhood of Subathu, is several hundred miles off towards the Indus, near Rawul-pindi. It is evident that the whole mistake, like so many others of the same kind, is traceable to the incorrigible carelessness of unscientific collectors in distinguishing localities when labelling their specimens. Geologists and Palæontologists ought by this time to be sufficiently warned on this point to be more cautious in speculating upon such data.

north-west and attaining a maximum to the south-east; this fact, as I have said, is apparent from a mere glance at the map. Already to south of the Sutlej a change has taken place from the normal state of the section in the Subathu area. The limestone band, which had for so long formed the boundary between the nummulitic rocks and the newer deposits, makes a sharp bend inwards. The direction of the boundary does not conform to this sudden turn of the inner contact-rock, so that beyond this point we find the Subathu group again; the limestone ridge has thus become bounded on both sides by the nummulitic beds, quite similarly to the ridge at Dundelee (see Fig. 10); it ends abruptly at a short distance to north of the river. On the west of this ridge, the bottom, fossiliferous beds scarcely appear at all, and to north of the Sutlej they are not to be found along either boundary, although, as before, both these boundaries are lines of denudation. In the central part of this Trans-Sutlej area however, north of Dihur, the soft bottom-beds are well exposed in several places; but in this position also, we soon lose sight of any recognizable rock of the Subathu group. The sandstones forming the Sid hill *may* be true representatives of the Kasaoli beds, but they have an equal resemblance to beds that cannot hold that pretension, and a little further in the same direction, at and north of Mundi, rocks come in of so decidedly new a type that I prefer describing the whole in connection with the upper groups of the Sub-Himalayan series. The fact which I now wish to elucidate is, however, independent of any strict identification of these new rocks; for if they do belong to the Subathu group they are very topmost beds; and as to the other part of the evidence there can be no doubt,—the whole group is here so depressed, that the bottom beds never once show again to east of Ravee, although the rocks are everywhere greatly disturbed; whereas to east of the Sutlej the very base of the formation is exposed throughout.

Mode of extinction of the Subathu group on the north-west.

Cutting out of the Subathu group on south-east.

On the south-east the mode of disappearance of the Subathu beds is the very reverse of what we have just seen to the north-west. For a long way before the final extinction of the group the bottom beds become more and more exposed, and at last none others are seen; their last appearance is at the top of the ridge. The final thinning out of the group is however too rapid to be due simply to the general rise I have described. From a little below the confluence of the Jalar and Giri the boundary slopes obliquely but rapidly up the ridge to the south; I do not believe it is a fault; the Blini limestone and conglomerate are well seen both in the river and on the ridge about Pagad; and, as I have said, the full thickness of the nummulitic beds seems to be exposed along the crest of the ridge. To this more rapid elevation of the area at this point the abrupt termination of the Subathu group is due. Although no sign of such a movement be traceable in the Nahun rocks on the south of the main boundary, it is quite intelligible that it may have occurred subsequently to, or synchronously with, the supposed great fault along the boundary, and have stopped out against it. It seems however to me much more likely that this easterly elevation took place long anterior to the Nahun period, and extended far to the south of the present boundary, that the denudation, which followed or accompanied this elevation, removed every vestige of the Subathu group from off the area to the south of the main boundary, and thus prepared the ground for the subsequent deposition of the Nahun rocks. The state of the small outlier of the nummulitic rocks east of the Ganges corresponds with the supposition I have advanced. It is well elevated on a base of the Himalayan rocks.

Probably anterior to Nahun period.

Irregular form of this boundary an assumption against a fault.

There is an argument I must not omit, although, being based upon an assumption, its force will depend upon the theoretical convictions of each individual. The very irregular form of this boundary is much against its having

originated in a great fissure. There are, as we shall see, true faults among these rocks, but they add force to the argument by confirming the opinion to which I appeal;—they are essentially rectilinear. It remains to be shown that the sharp irregularities in the main boundary, such as that just east of Rajpoor, and again that east of the Ganges, are not due to cross faults. For this I must refer to the following Chapter.

Analogy with pre-nummulitic elevation.

The fact for which I here contend is but the continuation, or rather the repetition of a process for the action of which in pre-nummulitic times I have already adduced evidence in discussing the relations of the Subathu group to the older rocks, namely, a slow upheaval of the area corresponding approximately, here at least, to the Lower Himalayan region, and involving the formation of a succession of coast lines along which the several Sub-Himalayan groups were laid down.

The following general remarks upon the fossils which I obtained from the rocks of the Subathu group are due to my colleague Dr. Kane, who very kindly made a careful examination of my small collection. The plant remains are exclusively from the Kasaoli beds, and from two localities; one in Kasaoli itself, on the lower mall, about a quarter of a mile south of the water-tunnel; the other locality is some miles north of Kasaoli on the Budi road, near the stream in the chief re-entering angle on the east side of the main ridge. The other fossils were obtained from the true nummulitic beds at the base of the group, and from scattered localities:—

A number of well-preserved plant remains were found in the rocks of the Kasaoli range. They are, probably, of middle tertiary age, and are embedded in an indurated shaly clay, bluish, and slightly micaceous. It is evident from the regularity with which these remains are disposed,—the leaves being in no case crumpled, or distorted, as well as from the fine texture of the rock in which they occur, that they have been deposited from water either perfectly still, or only slightly in motion; and it is also evident, judging from their comparatively perfect state of preservation, and the general evidence of their all being mature

and of their consequently having been separated naturally from the trees or plants to which they belonged, that they originally flourished in the vicinity of the rocks in which they are now fossilized.

The natural families represented by our specimens are *Sapindaceæ*, *Ericaceæ*, *Lauraceæ*, *Moraceæ*, *Cycadaceæ*, *Coniferæ*, *(?) Palmaceæ*, *Cyperaceæ*, and *Gramineæ*.

SAPINDACEÆ.—Only one leaflet seems referrible to the Sapindaceæ. It is, however, well-marked, and can be identified as belonging to the genus *Sapindus*. It approaches very nearly to the *S. dubius* of Unger, but it would be rash to refer it to any species without a comparison of other specimens from the same locality.

Living plants of the Soapwort family are essentially tropical, and flourish best in India and the tropical parts of South America.

ERICACEÆ.—Several of the specimens belong to the family Ericaceæ. A number of them seem to belong to the genus *Andromeda*, and, if not identical with the species *vaccinifolia*, described in the "Flora Tertiaria Helvetiæ," they very closely resemble it. In another specimen the capsular fruit, probably of an Andromeda, and a cast of the fruit, are preserved.

Living heathworts have no very characteristic habitat. They abound at the Cape of Good Hope, but they are also to be met with in Europe, and they are distributed over the New World, both within and without the tropics. They are rather rare in India and Northern Asia, and it is said that, when they occur within the tropics, they are only to be found on highlands.

LAURACEÆ.—The natural family, *Lauraceæ*, is well represented in this collection. Some of the specimens seem referrible to the genus *Persea*, and perhaps also to the species *Braunii*; others are undoubtedly of the genus *Laurus*. In one case a well-marked berry is preserved. It has an adherent, 6-partite perianth, and must, therefore, be referred to the Perseæ.

Lauraceæ have their natural habitat in cool places in the tropics of either hemisphere, and flourish well in the northern parts of India, and along the lower zone of the Himalayas.

MORACEÆ.—Some well-marked specimens of the natural family *Moraceæ* occur, all belonging to the genus *Ficus*, and one appears to be identical with the existing *F. religiosa*.

It would be indeed surprising, if in any Indian tertiary deposit, where exogenous leaves were found fossil, Ficus did not exist in considerable quantities. Lindley says, speaking of existing plants of this genus, that "it is one of those which travellers describe as most conducing to the peculiarity of a tropical scene."

CYCADACEÆ.—One specimen seems to belong to this natural family, but is not sufficiently well preserved to admit of satisfactory determination.

Living plants of the family, Cycadaceæ, are essentially tropical.

CONIFERÆ ?—There are several acerose, midribbed leaves, and fragments of cone scales which probably belong to the extensive family, *Coniferæ*; but they are too badly marked to admit of generic identification.

PALMACEÆ.—A very distinct *Flabellaria* occurs, closely allied to the *F. raphifolia* of Sternberg. Brogniart considers that Flabellaria should be referred to the Cycadaceæ, but all other authorities agree in classing it with the palms.

Much of the botanical physiognomy of tropical regions depends on the presence of palms.

CYPERACEÆ.—The natural family, *Cyperaceæ*, is represented by several specimens of *Cyperites*; some apparently identical with, or very closely allied to the species *Deucalionis* of Heer, and others to the species *Tenuistriatus* of the same author.

The genus Cyperus, the living representative of the fossil Cyperites, is essentially tropical. Humboldt remarks that the character of sedges changes as we approach the equator, multitudes of species of Cyperus usurping the place of arctic and temperate genera of the sedge family. The habitat of the members of this family is various. Lindley says :—"They are to be found in marshes, ditches, and running streams, in meadows and on heath, in groves and forests, on the blowing sands of the sea-shore, on the tops of mountains, from the Arctic to the Antarctic Circle, wherever phaenogamous vegetation can exist." Cyperites is such a genus as we should expect to have preserved in a tropical fresh water deposit. Royle (Illust., p. 415) says :—"Cyperus inundatus, probably with other species, helps much to bind and protect the banks of the Ganges from the rapidity of the stream, and the force of the tides; as in Holland Carex arenaria is carefully planted on the dykes, where its far-extending roots, by mutually interlacing with each other, fix the sand, and give strength to the embankment."

Associated with these specimens of Cyperites some fragments of Carices also occur.

GRAMINEÆ.—There are a few specimens of grasses in our collection, which might all be referred to the genus *Poacites.*

It may fairly be deduced from the facts here stated, that the climate and other external influences which prevailed during the deposition of these blue shaly clays of the Kasaoli range were very much the same as those which obtain now in the locality whence these vegetable remains have been derived. It has already been shown that these remains cannot have been conveyed far from the places where they flourished as living organisms; and we may conclude, if we allow for the elevation which the Kasaoli beds, in common with the whole mountain mass, have undergone, that the latitude in which the Kasaoli beds were deposited, at the time of their deposition, was, as now, generally favorable to sub-tropical forms of vegetable life. And that the relative disposition of sea and land in the Subathu period was essentially the same as now, or at least that the lower zone of the Himalayas was then, as now, open to the sea on the south, may, with much probability, be inferred from the fact that the fossil plants which we have been noticing are such as, when alive, would require constant accessions of moisture from sea-breezes. Judging from the great number of genera which we have represented in this small collection, it is likely that the vegetation of the Kasaoli period was rank and various. The presence of *Cyperites* and *Carex* suggests that they flourished in the vicinity of a lake or river, and the special function which *Cyperus inundatus*,—to which some of our specimens (Deucalionis) are allied,—at present performs, in preserving the banks of the Ganges, countenances the hypothesis that these Cyperites grew on the banks of the river, or a branch of it, which deposited the beds in which they are now preserved.

PROTOZOA.

Nummulites. Several species and numerous individuals .... Subathu.
Cristellaria (?) .... Dundelee.
Heterostegina .... Ditto.

CŒLENTERATA.

Thecosmilia .... Subathu.

CONCHIFERA.

Ostrea Flemingi. D'Arch.	Subathu.
——— multicostata. D'Arch.	Giri Valley.
Lima ——— (?)	Subathu.
Pecten ——— (?)	Ditto.
Lucina ——— (?)	Ditto.
Cyprina Subathuensis. D'Arch.	Ditto.
Astarte ——— (?)	Ditto.
Cypricardia Vicaryi *(var. a.)*. D'Arch.	Ditto.
Crassatella (?)	Ditto.
Myoconcha(?)	Giri Valley.
Cardita Dufrenoyi. D'Arch.	Subathu.
Venus pseudonitidula. D'Arch.	Ditto.
——— sub-Gumberensis. D'Arch.	Giri Valley.
Panopœa (?)	Ditto.

GASTEROPODA.

Natica epiglottina. Lamck.	Subathu.
Cerithium Stracheyi. D'Arch.	Ditto.
Turritella Subathuensis. D'Arch.	Ditto.

PISCES.

In two of the specimens from Dundelee remains of fish are preserved, but unfortunately not in a fit state for identification. One of the specimens shows little conical teeth which evidently belonged to some fish, and perhaps scales, while the other displays almost an entire body. The tail of the latter is wanting, and all that can be said to be well preserved of it are portions of the dorsal and left pectoral fins, both of which are spinose. The bones of the head are probably all present, but very much displaced. There are no distinct scales observable in this specimen, and the jaws show no trace of teeth. Thick-set and strong spinous processes, at right angles to the body of the vertebræ, give the abdominal part of the fish, where they are exposed, a peculiar annulated appearance. Judging from general appearances the statement may perhaps be hazarded that our specimen belongs to the order Ganoidei.

CHAPTER IV.—*Sub-Himalayan Series: Nahun and Sivâlik Groups.*

Nahun and Sivâlik Groups.

THE rocks of the region, orographically denominated *Sub-Himalayan*, present great similarity in primary characters, with much complexity of structural relations. We can trace one tolerably well defined division in these deposits, based upon a general unconformable contact, and hence the distinction of a middle and an upper group, under the names of *Nahun* and *Sivâlik*. In many sections we shall find evidence of the same kind, suggestive of further sub-division at least locally; we cannot, however, notice this further than admitting its testimony as to the cotemporaneous action of disturbing and of formative causes.

Eastern and western regions.

Were our notice to be limited to the region east of the Sutlej, it might be most convenient to separate the description of the two upper members of the Sub-Himalayan series. Throughout this region it is possible, in almost every section, to draw an exact boundary between the Sivâlik and the Nahun groups. Beyond the Sutlej, however, the relation of the two is much obscured: we find, along very definite lines, rocks which we can with certainty pronounce to be the continuation of the Middle rocks; but intimately associated with these, up to the very base of the inner mountains, there occur strata which, as far as I can prove, may be represented among the undoubted Sivâlik rocks of the outermost hills. This difficulty will be fully illustrated in the sections and the descriptive text; in the map, however, I prefer adopting the purely arbitrary measure of colouring all the outer rocks west of the Sutlej as Sivâlik, to the ambiguous one of mapping an uncertain and possibly unreal boundary; the innermost band alone is here coloured as belonging to the middle group. It is in narrow bands along the lines of disturbance that the lower rocks

appear in every case, and these lines are carefully mapped. The contrast I have just indicated between the relations of the two groups in the east and in the west of our district suggests a difference in conditions of disturbance as affecting these two regions. For the reasons above stated, I will separate the description of these two regions, adopting the east end of the Pinjore Dun as the line of demarcation. In each I will, to some extent, combine the description of the two groups: they are mutually illustrative.

Relation to the older rocks.

The relation of the Nahun group to the older rocks has been already noticed in the third Chapter. I have there stated my opinion, that the junction is primarily a line of original contact, possibly modified by subsequent faulting. This view of the case will be exemplified by the facts to be discussed as to the relation between the Nahun and Sivâlik groups; and it will be again examined with reference to the structural conditions of the whole region.

General relations of Nahun and Sivâlik rocks. Previous notices.

The opinions that have been published regarding these Sivâlik and Nahun rocks are various and contradictory, having been in most cases formed from unconnected observations, and without reference to previous notices. Thus, Herbert in 1826 (his memoir, however, was not published till 1842, in Vol. XI., Jour. As. Soc., Ben.,) remarked the resemblance of the massive sandstones of the Sivâlik hills to the similar rocks (of the Nahun group) at the base of the Naini Tal hills, and conjectured their identity, colouring them as one band on his map. He assumed them to be of Saliferous age, and having, by an equally groundless assumption, supposed the sandstone of Delhi to be Old Red, he actually made a number of borings in the Doab in search of coal.

Herbert, 1826.

Cautley, 1836.

Cautley in 1836, (Trans. Geol. Soc., London, 2nd Ser., Vol. V.) from fossil evidence (*vide* p. 15), identified some of the higher beds of the section at Nahun with the bottom beds of the Sivâlik range. From the uniformity of the northerly

dip, he further conjectures that the highly fossiliferous rocks of the lower hills, south of Nahun, are *lower* members of the same series; and, consistently with this view, accounts for their non-appearance east of the Jumna, by the lesser upheaval in that region. In the same paper he calls attention to the fact, that in the Nahun region the Sivâlik hills are united to the greater hills, as affording an opportunity of discovering the relations of the two series of rocks; thus, we must presume, he was not aware that the Nahun rocks are uninterruptedly connected with rocks that are largely exposed along the foot of the hills to the north of the Dehra dun, where they are equally in contact with the older rocks.

R. Strachey, 1851.

R. Strachey in 1851, (Quar. Jour. Geol. Soc., London, Vol. VII.,) describing the section south of Naini Tal, where the Sivâliks are exceedingly ill developed, only the topmost conglomerate beds appearing, and where the Nahun group is remarkably well developed, falls back upon the extreme view regarding the latter; adopting the same opinion as Herbert, that they are of "the Saliferous age, and the extension of the strata containing rock-salt which we find on the same general line further to the west in the Punjab" (? the Mundi salt rock—*vide* p. 60). We will see that the Naini Tal sandstone also is almost uninterruptedly connected with its equivalent at Nahun.

Vicary, 1853.

Vicary in 1853, (Quar. Jour. Geol. Soc., London, Vol. IX.,) describing the section of the Pinjore dun, remarks, that on the north of it there occurs sandstone not unlike that of the Sivâliks, but that he had never found fossils in it. In his section, however, he represents it as normally *underlying* all the rocks of the Kasaoli range.

Greenough.

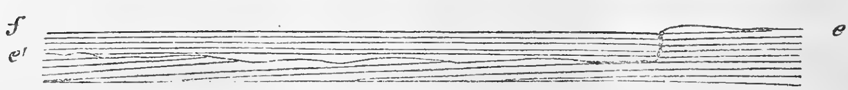
In Greenough's general geological map of India there is but one colour given to the whole series of rocks from the Subathu to the Sivâlik group. But I conjecture, from the fact of a separating line being engraved, that the author

intended to distinguish between the Sivâliks on the one hand and the Nahun and Subathu group on the other. The map was published after his death.

Possible occurrence of Nahun beds in Sivâlik sections.

Cautley was, no doubt, correct in pointing to the Nahun region as the most likely ground in which to establish the connection of the Sivâlik rocks with those to the north of the duns, not knowing that in identifying the Nahun rocks with those at the outer base of the Sivâlik hills he had himself welded the first link of the chain. Whether or not this idea be confirmed (I have already (page 15) given my reasons for doubting it), there can be no question that the rest of his section at Nahun is erroneous; the highly fossiliferous, conglomeritic, soft rocks about Deoni and Jabri, in the valley of the Markunda, south of Nahun, are unquestionably more recent than the Nahun rock, from the debris of which they were principally formed, and against the denuded edge of which they were deposited. So that, should the disputed identification be ultimately established, it will involve the division of the section in the Sivâlik hills, and not the union of all these rocks with those at Nahun. The supposition we shall then have to make regarding the process of formation will be but a slight modification of that which must be independently adopted,—a slow and partial upheaval of the Nahun rocks along the edge of the area of deposition, involving their partial denudation and erosion, and the deposition of the upper group in very approximate parallelism of stratification, such as it might be difficult, if not impossible, to detect, when the two became subsequently contorted together. I have given an imaginary section of such a state of things in Fig. 11. Were the strata there represented to become contorted, it

FIG. 11.



Possible original relation of Nahun and Sivâlik groups.

might be possible, only by fossil evidence, to disconnect the bed *é* from the overlying series and to connect it with those at *e*.

The only view that can be taken of the section differs in no essential particular from the case I have just supposed in explanation of the doubtful identification. There is no evidence, such as I have been able to show in the case of the Subathu group, that the Nahun rocks were entirely removed from the present area of the next younger group; on the contrary, we see some cases of distinct, though limited, overlap along the boundary of the two, and there is no kind of improbability in the appearance of the underlying rocks at any point of the disturbed area to the south of this general boundary. Thus, then, the confirmation of Colonel Cautley's identification would in no way affect the establishment of a younger group, distinct from that of Nahun, typically developed in the Sivâlik hills, and the chief depository of the Sivâlik fossils; it would only be the detection of a reappearance of the older group, due to upheaval and denudation, beneath the newer one at the south base of the Sivâlik hills. Should the fact be established, it will afford an admirable illustration of the great assistance of palæontological evidence in the elucidation of stratigraphical phenomena; and, on the other hand, the stratigraphical facts would warrant the expectation of some distinction between the fossils of the two groups; no such distinction has as yet been suspected by the authors of the "Fauna Sivalensis."

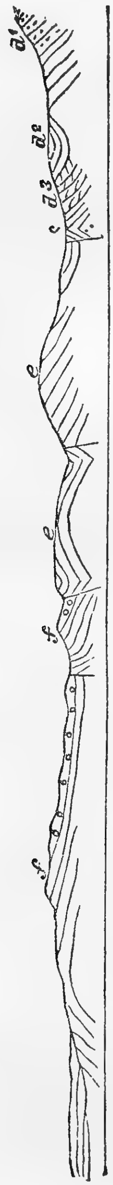
There is one more suggestion I would offer for the benefit of any future explorer, who may be fortunate enough to re-discover the fossiliferous deposit north of Nahun:—to examine whether it may not be local, an outlying remnant of some swamp-deposit on the shore of the ancient Sivâlik estuary, lake, or sea.

Bearing upon the theory of disturbance.

This moot point of identification is of much importance, as bearing upon the most interesting problem in physical geology,—the manner of upheaval and disturbance. We will see that the rocks of the Nahun group exhibit a greater gene-

rality, and a higher degree, of disturbance and of upheaval than is found in the Sivâlik strata. These latter are found at many points resting undisturbed against the highly inclined beds of the Nahun group, and where, moreover, the supposition of a fault is inadmissible. If, notwithstanding this, we are to find at so short a distance as the outer base of the Sivâlik hills the upper group resting in apparent conformity upon the lower one, a very important limitation would be put to our speculations upon the nature of the disturbing causes. On the other hand, I must mention that we find in the sections of the Sivâlík rocks themselves examples that may be applied retrospectively to sanction such a supposed anomaly. At many places, from a condition of original repose, they are found within a short space turned up to the vertical, or even inverted; thus we are at liberty to suppose a state of disturbance in the Nahun group, prior to the deposition of the Sivâlik rocks, similar to that now displayed by this latter group.

FIG. 12.



Section at Nahun. *c.* Krol group. *d.* Subathu group. *e.* Nahun group. *f.* Sivâlik group.

Actual section at Nahun.

We may now examine how far an original relation of these two groups, such as shown in Fig. 11, or supposing, as we must, the disturbance and erosion of the lower strata to have been greater than is there represented, is compatible with the actual sections. The actual section north and south through Nahun is seen in Fig. 12. The generally contrasting stratigraphical features of

the two groups are by no means well exemplified in this section, the Nahun rocks being far less disturbed than usual, but the immediate contact is typical, at least for this region between the duns. In the valley north of the town thick brownish gray sandstone and nodular clays are nearly horizontal near the contact with black slates and the nummulitic rocks. On Nahun hill these sandstones and clays have a moderate dip to north. The Markunda flows for some distance through the Nahun rocks, obliquely to the strike before reaching the outer junction, along which it takes a bend for a few hundred feet. The view here is a very striking one to the geologist, especially if he be to any extent acquainted with the two groups here seen in contact ; it is represented in Plate I. looking westerly, down the river, to the bend, where it again turns southerly ; there is a vertical north and south cliff of the outer rocks, running into a steep, east and west cliff of the Nahun beds at about half the height. Everything conspires to increase the contrast; the Sivâlik beds are thick, soft conglomerates, sands, and clays of a dull earthy brown colour, and have a remarkably steady dip of 25° to north, thus going apparently under bright brown, purplish red clays, and gray soft sandstones of the higher part of the hill. Indeed the superposition is more than *apparent* ; however abnormal, it is to a small extent actual; a vertical plane, starting from the younger rock upward, would certainly cut off on the south some of the older ones above. The dip in these is higher in the same direction, and considerably crushed, suggesting, if nothing else did, that all are not in order ; the appearance, however, is so deceptive that previous observers, who cannot have failed to notice so conspicuous a section, have interpreted it as a case of normal sequence. All the large boulders in the conglomerates are of a rock undistinguishable from that of Nahun.

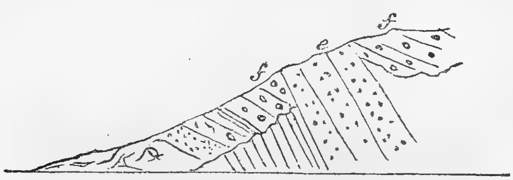
In this junction we have a very fresh instance of a structure that has often attracted notice, and is still a puzzle in the sections of Alpine regions ; a more complete case could not be found. In highly contorted

districts this abnormal order of superposition is a feature of what some authors understand by the *fan structure,* in which case inversion is involved. In less disturbed regions, and generally as here, in the fringing zone of mountains, such sections are usually supposed to necessitate prodigious faulting; for the younger beds at the contact are the topmost of a series many hundreds (perhaps thousands) of feet in thickness, as ordinarily measured, and the older ones are the bottom beds of a series equally thick. This mode of explanation by faulting is a most convenient one, and seems to harmonize well with, or even to be suggested by, the general facts of the case, especially that most prominent one, the upheaval of the mountain area on the upthrow side of the supposed fault. The idea of the very recent upheaval of great mountains has been largely based upon analogous sections to these; yet in the case before us it will, I think, be evident from the following sections *that no fault at all has occurred.*

The Tib section, an original contact.

On both sides of the Markunda valley, along the junction, where the conglomerate band runs close up to the Nahun beds, in the narrow and steep gullies draining to the south, the contact is better seen than in the main river. In this position, on the path leading from Tib village to Kairwala, a section of the contact occurs as represented in Fig. 13, and it must, I think, be taken

FIG. 13.



Section of contact south of Tib. *e.* Nahun group. *f.* Sivâlik group.

as a type and a clue for the rest. The beds *f* are the actual continuation of those we have just seen in the Markunda; and so are the beds *e.* Here, however, it is palpable that they are nearly in their original relations, and that the beds *f* were deposited against a steep

denuded bank of the beds *e*, which probably were also more or less tilted at the time of formation of the younger deposits. The difference between the two sections, at Tib and in the Markunda, may be explained by supposing that the bank or cliff was less steep at Tib, but chiefly, and more generally, by the admissible assumption that the lateral compressing force, to which we may attribute the reverse underlie of the contact in the Markunda, and elsewhere, met with different conditions of resistance in the Tib section. The contact exhibited in this little section precludes the possibility of a fault, and, if there be none here, it were gratuitous and against probability to suppose any in the Markunda section. I believe, therefore, that the overhanging contact in the Markunda section is entirely an effect of a contorting force upon a very steep edge of deposition.

Its modification by lateral compression.

The interest attaching to this explanation is very great, for the phenomenon to which it is applied is one of very extensive occurrence, and the usual modes of accounting for it, by inversion or by reverse faulting, involve the conception of causes and conditions from which it is a relief to find even a partial escape.* But there are, of course, corresponding difficulties introduced: the amount of lateral yielding must be inversely as the steepness of the original junction, and directly as the depth of the contact which has to be accounted for. Thus, I can conceive an original contact, like that in Fig. 14, resulting,

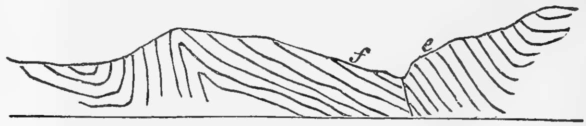
FIG. 14.

Original junction of succeeding deposits.

* It is evident that the explanation given of the reversion of this natural junction is applicable also to reverse faults; a fault that was originally normal might, by a very moderate amount of unequal lateral movement, become reversed.

through slow lateral compression, in such a section as that in Fig. 15,

FIG. 15.



Possible effects of compression in producing folded flexure and apparent reverse faulting.

which is very like that seen in the Markunda. The younger strata being softer, and also probably less weighted, would yield most, thus inducing the reversion of the line of contact. There can be no hesitation as to the existence of the cause to which I have appealed; for, the prodigious contortions of the strata in these disturbed regions admit of no doubt that boundless tangential forces have acted upon the earth's crust, one *vera causa* for which forces we find in the more or less local depression of that crust.

Dun formation.

The section at Tib is illustrative from another point of view,—it exhibits the initial stage of dun formation. It is, in fact, the geological limit of the Kyarda and Dehra duns, these two forming but one geographical feature. A few score yards to the east of Tib the boundary retreats rapidly northwards, and at several places, as on the bank of the Markunda, near Kujurna, the slightly inclined conglomerates are found resting on the Nahun beds.

Section at Simbuwala.

At Simbuwala, a mile and a half to the east, the feature is more completely developed, here the Markunda runs along a miniature dun; the conglomerate beds of the contact-section in the lower Markunda continue steadily along the same strike, and with about the same dip beyond the deflection of the boundary near Tib, and from this point they form, more or less continuously, the crest of the Sivâlik range of hills. In the ridge just south of Simbuwala, these thick clay and sand conglomerates dip at 40° to north 30° east; in the banks of the river, about 100 yards to the north, the dip is reduced to 20° and 15°; and further

still in the same direction, in the precipitous bank of the immediate river-valley, the same beds are quite undisturbed; Fig. 16 represents

FIG. 16.

SIVÂLIK RANGE. NAHUN RANGE.
Section at Simbuwala.

the section here. Examined independently in this locality, or, as better exposed in the banks of the Batta, these conglomerates would inevitably be looked upon as recent valley deposits. I cannot, however, but consider them as of true Sivâlik age,—as partly deposited prior to, and partly cotemporaneous with, the disturbance now so extensively exhibited in the rocks to the south; the identity of the two deposits is complete, as is also the gradation of disturbance.

If the interpretation I have given of this last section be correct, it enables us, in conjunction with that of the Tib section, to exhibit an important point,—the commencement, and even the extensive progress, of the contorting action prior to the Sivâlik period: for it must be supposed that the inner band of rocks north of Simbuwala had been greatly tilted before the conglomerates were laid against them. We will find evidence in other sections (as in the Sutlej and Sursulla) that the same forces were in action subsequent to the deposition of the same conglomerates. We are thus compelled to distribute the resultant effects over an extended period. Such in fact is the general impression made by the study of the Sub-Himalayan zone, namely, the continued action of a general disturbing force, the effects of which were varied in time and place by local conditions.

Protracted process of contortion.

I have taken the earliest opportunity to notice the junction about Tib, because I believe it to afford a key to many others: it is in the nature of the case that this clue should be found in the relations of the most recent rocks. The

Importance of the Tib section.

confirmation it affords to the explanation I gave of the relations of the Subathu group to the Krol and Infra-Krol strata is very strong; the *primâ facie* evidence there being strongly in favour of faulted junctions. We must be cautious, however, not to force this new precedent too far, the more so, as there would seem to be an antecedent probability of the two phenomena appearing together; an original junction, such as I have shown to have existed in some of these sections, would surely be influential in pre-determining the position of subsequent vertical displacement. There seems especial need to introduce the partial influence of faulting in the case of the main junction of the Nahun group with the Subathu group and with the rocks of the Lower Himalayan series, because the strata in contact are so contrasting, and there is so often the appearance of a quasi-fault rock at the junction; I think, notwithstanding, that we are called upon to explain such cases as far as possible by the mode of action so clearly indicated in the Tib section.

The middle group of eastern region.

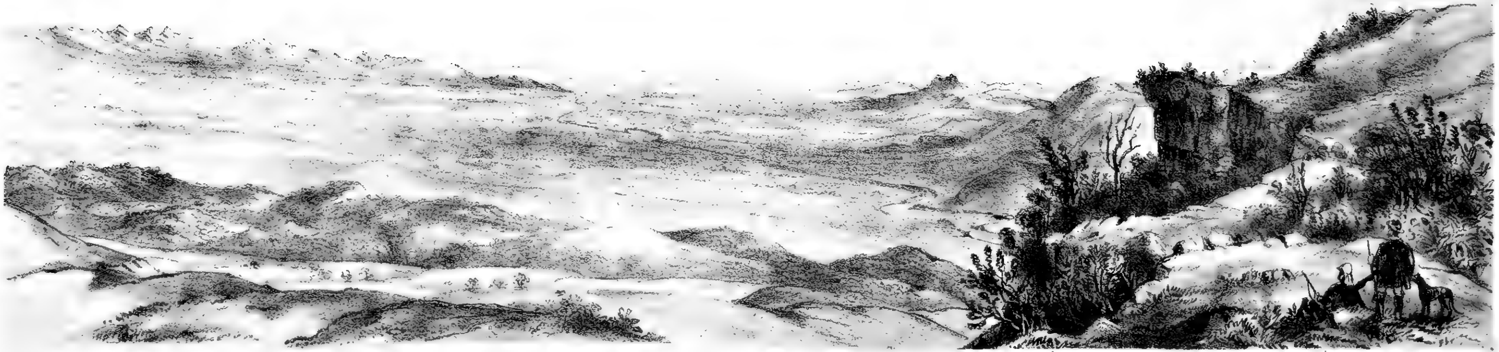
Having now explained the grounds upon which the Nahun and Sivâlik groups are separable, I will rapidly notice the peculiarities of each. A glance at the view either from the heights on the north or from the duns on the south is enough to suggest that the band of rocks which at Nahun forms so well-marked a step between the Sivâlik hills and the outer ridge of the Lower Himalaya is continued along the north side of the duns. Such a view, taken from a moderate elevation on the flanks of Budraj, near the village of Mundresu, and looking westward across the Jumna to the contraction of the Kyarda dun, is represented in Plate II. In some few places there is no distinct

Its extent.

flanking ridge, but it is rarely that there is no section seen to establish the constant presence of this band of rocks at the base of the Lower Himalaya. The Nahun range itself continues undiminished up to the Giri, the narrow transverse gorge of the Batta being only a momentary interruption to it. Between the

Pl: II.

Calcutta.



H L Frazer Lith. Calcutta.

VIEW, LOOKING W.S.W. FROM BUDRAJ, OF THE JUMNA, THE DHERA AND KEARDA DUNS, AND THE SIVALIK HILLS.

Giri and Jumna there is no ridge, its place being occupied by an immense talus of debris. In the Tonse, the Omlao, and the Jumna there is a narrow band of Nahun sandstone well seen, in contact with the slate rocks. Immediately east of the Jumna the low hills again appear. They are very typically developed immediately under Masuri. It is in the eastern portion of the Dehra dun that the greatest blank occurs in the band of Nahun rocks; between the Ruspunna and the Ganges I did not find it once exposed; here, as to the west of the Jumna, a very deep talus of detritus covers the base of the mountains. The Nahun sandstone shows, however, in the Ganges opposite Riki Kase, in the very angle of the sharp bend which there occurs in the boundary, so it is highly probable that it is continuous beneath the bank of detritus to the west. From Riki Kase southwards the section is again covered and obscured; a trace of the sandstone is seen in the Tal, and there appears to be a narrow remnant of it left between the Sivâlik conglomerates and the slates at the angle north-east of Moondhal, where the boundary turns eastwards. This north and south line from Riki Kase is the termination of the great dun, and it marks a great change in the development of the Nahun band; from the Ganges eastward, as far as the frontier of Nepal, this band forms uninterruptedly a much wider and more lofty belt of hills than anything we have as yet seen to the west.

Difficult boundary in the duns.

It may be noticed that the south boundary of the Nahun group throughout the duns is mapped conjecturally, its vaguely curved form in this position contrasting with its sharply irregular outline in the Nahun region. The uncertainty in mapping this boundary depends upon the difficulty in deciding between superficial and true Sivâlik deposits,—a difficulty that may have been anticipated from the Simbuwala section. In the region of continuous hill, about Nahun, the boundary can be traced with considerable exactness, and it is seen to be most capriciously irregular; at

one spot, in the Roon, there is a complete interruption to the Nahun band, the upper Sivâlik clays being in contact with the Subathu group.

Lithological character of the Nahun band.

Regarding the lithological characters of the Nahun group here, there is little to be said. Throughout the entire distance from Nepal to the Pinjore dun the fine sharp, gray, soft sandstone, which, in its essential characters, is so characteristic of the whole Sub-Himalayan series, almost exclusively prevails. It occurs in massive beds often fifty and a hundred feet thick, and showing little or no trace of lamination. It is in this rock that lumps of lignite are very frequently found. The clays, occasionally interstratified with this sandstone, are generally gritty, nodular, and ferruginous, and are most abundant in the lower part of the group, on which account they are best exposed along the outer boundary. The iron-ore worked at Dechouri and Kaladoongi, at the foot of the Naini Tal hills, is one of these ferriferous clays; and beds of analogous character can be traced far to the westwards, as, for instance, in a gully opposite Kolur, on the north bank of the Batta.

The Sorna conglomerate.

The most remarkable exception, within this district, to the general uniformity in composition, is to be seen in the section of the Sorna glen, under Masuri. There is a massive band, 400 feet thick, of coarse boulder conglomerate; in composition it most closely resembles the very uppermost beds of the Sivâlik conglomerate, such as are seen in Nagsidh and Motichur hills, or the still more recent deposits, in the gorge of the Ganges. The boulders are thoroughly water-worn, and almost exclusively made of the hardest subschistose quartzite, such as are only found in streams coming from the heart of the mountains. This feature is, no doubt, significant, as it contrasts most markedly with the composition of the conglomerates in an apparently analogous position in the sections about the Sutlej in which the debris is chiefly local. This mass is equally strange in its mode of occurrence; it appears, with little or no transition of characters

over the fine lignite sandstone, near the inner boundary, the dip of the whole section being 80° to north-north-west. Notwithstanding its considerable thickness, I could not find a trace of it in the similar gorges, to east or west.

The lignite sandstone shows prominently for some way beyond Nahun to the west; about the Morni lakes it is very well exposed. In this neighbourhood we find one of the few instances in which this rock comes in contact with the similar rock of the Subathu group. The contrast in the texture is most striking: on the gap just south of Morni one steps at once from the hard angular debris of older rock to the rounded sandy surface of the newer.

Disturbance of the Nahun band.

In the Figures 12 and 16, the general condition of the Nahun rocks is sufficiently indicated; the strata are usually more inclined than in the sections there represented, being often vertical throughout nearly the whole thickness of the band. The dip is, with few and only local exceptions, towards the older rocks. The underlie of the plane of contact can be well seen in some of the narrow gorges below Masuri, pointing steadily northwards, thus producing abnormal superposition. There is a very peculiar feature in the horizontal outline of this boundary, as exposed in the eastern portion of the Dehra dun, namely, its sharp bends. I have already appealed to this fact as almost precluding the supposition of this boundary being one continuous fault of enormous throw, but there is a supplementary supposition by which that view might still be maintained;—the sharp step-like form of these irregularities suggests the existence of cross-faults. We do not, however, find a single fact of detail to corroborate such a view. In that marked example of the Kalunga ridge, east of Rajpur and Dehra, the boundary runs directly for five miles to north-by-east, at right angles to the direction of the Masuri ridge, at about its middle, the angle of the boundary being only four

Steps in main boundary not cross faults.

miles distant from the crest; yet on that ridge we find not a trace of such a transverse break. It is fortunate this example exists, for one might be tempted in the greater case, just east of the Ganges, to take as evidence of this kind the distinct termination of the Masuri range about this meridian. A more immediate argument against this notion of cross-faults is the general fact that in every case of these bends the strike in both rocks approximates more or less exactly to the direction of the boundary. This fact, if not quite unaccountable on the supposition of cross-faulting, certainly lends it no support. The entire result is however in keeping with the view I have been advocating: namely, that it is a natural boundary. The position of strata exercises a great influence upon their mode of yielding to all kinds of denuding forces. We have seen in the section of the Hewnulgur that the Infra-Blini rocks of this region exhibit great irregularities of disturbance; hence, then, the irregularity of this boundary, which I regard to be, *quam proxime*, an original one; hence also the coincidence of the strike of the inner rocks with the direction of the boundary. The coincidence of strike of the Nahun beds would equally follow from the mode in which I would account for their contortion by a slow compressing force, throwing off masses of unequal elasticity at right angles to their original surface of contact.

The step in the boundary at the Ganges is coincident with an important change in the relations of the younger rocks. The Nahun rocks are far more prominently displayed to the east of this line than to the west, and the Sivâliks undergo a kind of reciprocal extinction. At Riki Kase the sandstone beds are vertical, with a northerly strike. In a line nearly due south of this, at the opening of the Mitiwali *sote* (torrent) the same rocks are in contact with the Sivâlik conglomerates, and both are vertical, with a strike to north-by-east; up the sote, however, after a space of uncertainty, the dip becomes steady to north-east, the strike thus conforming to the new direction of the boundary.

Sivâlik group of eastern region.

Having indicated the extent of the Nahun band in this region, that of the Sivâliks is also fixed. The same doubt applies to both along their boundary in the duns, owing to the great difficulty of assigning a limit between the Sivâliks and more recent deposits; the section in the river Noon will illustrate this point. On the score of composition there is much more to be said of the younger group; both vertically and horizontally its strata exhibit some remarkable variations. It were a deliberate error to seek for general regularity or definiteness in deposits that were so palpably accumulated under local influences, but, roughly estimated, there may be four divisions made in the Sivâlik series where it is most developed,—in the range separating the Dehra Dun from the plains, to which the name, Sivâlik, was originally exclusively applied. The lowest of these sub-groups of strata is the least marked, as it is also the least exposed, its base being unknown. Its only peculiarity is a greater prevalence of clays than in the portion of the series immediately overlying it; still, even here the thick-bedded sandstones predominate. Above this comes a thick band of massive sandstone with scarcely a parting of clay, or on the other hand, with only an occasional small pebble. Passing upwards, strings and beds of pebbles make their appearance, increasing into massive banks of conglomerate, but still with a clear sand matrix. The change is rather abrupt into the fourth stage of deposits, consisting of thick-bedded stiff clays and coarse clay-conglomerates. The crests of the passes and of the inner portion of the range are of this top band; it also occupies the area of the dun. It is important, however, to know that it is in no degree a dun-formation: this point is strongly suggested by the fact, just mentioned, of its forming the inner slopes and crests of the Sivâlik hills, and with the same steady dip as the rest of the group; but it is put beyond a question by the fact of the re-appearance of these same beds at the most south-westerly point of the whole range, to the

Lithological variations.

A general sub-division.

right of the Ganges, where the rocks on the south of the great longitudinal anticlinal are preserved; at the top of the reverse section, three miles east of Myapoor (Hurdwar), the clay conglomerates are seen dipping at 80° to south-west; we may then conclude that they once existed over areas where they do not now appear.

Thickness.

It is the two lower sub-divisions of the series which are liable to be identified with the Nahun band. The thickness of these accumulations is so very great and variable, that one must be content to indicate some standard examples; at the locality last mentioned there is a very steady section; starting from the Bheemgoda fault, the end of the main anticlinal axis, north of Hurdwar, at about the base of the second sub-division, with a steady dip of about 25° to the south-west, there is a continuous section for more than four miles across the strike ending in the clays and conglomerates, the dip having gradually increased to 80°. Taking 45° as even below the mean dip, we thus have a thickness of only a portion of the group amounting to 15,000 feet. That this enormous thickness of one series of strata was once regularly super-imposed in vertical succession, is almost incredible, yet I see no satisfactory solution of the difficulty, the youngest clay beds exhibit in the southern section the maximum of disturbance, and we are, therefore, scarcely at liberty to suppose the top beds added on each side during the process of disturbance.

Horizontal variations.

No two sections, that I have seen, of these rocks are exactly alike, even in passes not more than three or four miles apart, but this is only what we should expect in such strata. There are, however, general changes of much interest. From some little way to west of the Jumna there is a very marked increase in the proportion of clays throughout the group. The same is to some extent noticeable in the Nahun group; there are certainly more clays in the section of the upper Batta than in the gorges of the Sorna or the Noon. The well marked changes in the quantity and

quality of the boulder deposits are very suggestive as regards the physical conditions during the Sivâlik period; at least they leave no doubt upon some important points. The greater accumulation of boulder deposits in the immediate regions of the great rivers is very noticeable. This fact happens to be most conspicuously seen in the case of the Jumna; the thickness of sandstone-conglomerate in the cliffs of Amsot is remarkable. Throughout the Sivâlik hills proper the general description of the materials of these deposits is the same; with a greater or less amount of the debris of limestones and of other rocks that may be derived from the Masuri ridge, there is a large admixture of the same boulders as are now only to be seen in the beds of the great mountain torrents, a schistose quartzite being the prevailing variety. The rapid suppression of the Sivâlik rocks to the east of the Ganges prevents our carrying the comparison in that direction, but west of the Jumna there is most complete evidence of the changes. In the hills south of Kyarda, we still see the same description of debris as on the east of the Jumna: this is not merely the case in the northern portion of the range, it also holds good at Simulbari in the southern ridge, formed by conglomerates evidently in continuation with, and the representatives of those just south of Kolur. At this latter place, however, the conglomerates are as prominently made up of hard purple sandstone identifiable with the rocks of the Subathu group, such as now abound in the bed of the Batta. It is only in the small pebble-conglomerates at the base of the sub-group, that the detritus of the older rocks is still traceable; and in this position in the section it is constant throughout the whole district. Within a very few miles to the west another change is effected. It has already been brought to notice that all the larger debris in the conglomerates of the Markunda section is of Nahun rocks. The fact, that in the form of debris this distinction is clearly marked, is strongly confirmative of the separation that has been made between the Subathu and Nahun groups, and of the very decided separation from both of the strata now containing this debris.

It seems not unlikely that the changes we have noticed in the distribution of clay in the lower part of the group may be an early result of the same cause that produced the different distribution of boulders in the upper beds, namely, the influence of the great rivers; yet, in opposition to this view, it may be asked, owing to what change in these conditions at a subsequent period could clays accumulate so freely in the topmost strata, and cotemporaneously with coarse boulders, over the whole area. The mode of formation of these latter deposits is to me a very puzzling question, and seems to require the hypothesis of some diluvial agency. The theory of glacial action is hardly admissible; the thoroughly rounded condition of the boulders and the regularity of the stratification require some other explanation of the formative conditions of these beds.

Disturbance of Sivâlik group

The state of disturbance of the Sivâlik group exhibits considerable local irregularities. This is even the case in the detached ranges where there is no very evident cause for such breaches of symmetry. In these cases we may, I think, fairly attribute them to the internal conditions of the strata themselves. The very unequal accumulation of great banks of conglomerate cannot but result in the confusion of stratification in the more regular deposits with which they are associated, when all come to be compressed together. In the region between the Kyarda and Pinjore duns, we can generally trace these variations of dip to the irregularity of the boundary with the older rocks. The rule already noticed in the case of the Nahun group along the main boundary is equally well observed in the Sivâlik strata at their contact with the Nahun group. There is a remarkable example of this just to the west of the Markunda section: the boundary takes a sharp turn to the north-north-west, and along it the boulder-conglomerates dip steadily at 80° to east-north-east along the Shilani valley, nearly to Myndar hill, where the strike bends round to north-west. There are of course cases in which it would be vain to assign the immediate cause of the state of upheaval:

in hills south of Nahun;

Laika hill, over Shilani on the west, offers a striking instance of this. On the south of this hill, in a tributary of the Markunda, near the village of Meintappel, there is an excellent section: the finer conglomerates with sand and clays have a steady dip of 10° to north; from this they are seen to turn up without a break, and within a radius of ten yards, to a dip of 80° to south, and this dip obtains throughout the whole hill-mass, through an enormous thickness of strata in a descending section. On the north of Laika, the descending section from the Shilani conglomerates passes right across the base of the hill, the northerly strike going nearly at right angles to that of the strata on Laika; on the east and west the dips are almost as transverse as on the north. In such cases as these one must introduce faults, and be content with very vague conjectures as to the immediate causes of them. West of the Roon the dip of the Sivâlik strata is much more regular, at a low angle to north-north-east, up to the very contact. Here, in every section that I examined, the abnormal superposition of the older rocks is as well marked as in the Markunda.

in Sivalik range.

The Sivâlik range, south of the Dehra dun, is for the most part formed on the northern side of a great irregular anticlinal flexure. The local dip varies very considerably, but there is a line along the south base of the chain, inside which the dip is invariably to some point between east and north; near the axis the dip often amounts to 40° and 50°, but in all the sections it lowers gradually to where it passes into the more or less horizontal strata of the dun, in a manner quite similar to the type section of Simbuwala. At almost every point along the southern base, we find the beginning of the reverse southerly dip, and in two places, one on the right bank of the Jumna, and the other on the right bank of the Ganges, the section of the rocks on the south of the anticlinal is nearly complete; and in both we observe the very opposite tendency to that described on the north, namely, in a direction from the axis the dip increases rapidly almost to the vertical. Thus we have a well characterised example of what

Mr. Rogers has called the *normal flexure* (Geology of Pensylvania, Vol. II., p. 889.)

Transverse fracture in river gorges.

At each of the great transverse river gorges there is a complete break in the continuity of the anticlinal flexure, no doubt, involving transverse faulting. The stereotyped form of explanation for such coincidences is, that the pent up waters made a natural selection of these transverse fissures along which to carve out their course to the lower level. It seems to me to be open to discussion in this instance whether we should not thus be "putting the cart before the horse," whether the rivers, for the existence of which in this position during the Sivâlik period, we have such good evidence, may not have been the predetermining cause of these transverse fissures. In the case of the Ganges there is little to induce us to adopt an hypothesis so apparently extravagant as that just proposed, since we have at hand so plausible an explanation in the great abrupt bend of the boundary of the main mountain range,—an explanation which is also in accordance with the general hypothesis adopted for the mode of contortion of these rocks, for it might well be supposed that so great an irregularity in the line of resistance to the compressing force would be sufficient to produce such a transverse break as that in the gorge of the Ganges. We must indeed allow some influence to this cause. As, however, in our argument against the supposition of cross-faulting of the main boundary, the bend at Kalunga served as a check upon that east of the Ganges, so, in the present case, we must modify our interpretation of the Ganges section by that of the Jumna; the features of contortion in the two are strangely similar, and in the case of the Jumna there is no trace of a projection of the mountain area ; on the contrary, the gorge faces a wide recess of the main boundary.

The gorge of Hurdwar.

In approaching Hurdwar from the south the structural conditions of the rocks are discernible from a distance. As far as the eye can reach to the west, the face of the Sivâlik range presents a very broken series of bare cliffs, formed by the

scarped edges of the massive strata of clear gray sandstones which lie on the north of the anticlinal, and all of which dip to the north. For some miles, near the Ganges valley, the hills rise less abruptly, and are covered with jungle. The strata here dip southwards, on the south of the anticlinal, which strikes the Ganges near Bheemgoda, to the north of the main mass of the range. Eastwards, across the Ganges, the usual structure of the range is restored : in the grey cliffs of Chandi Devi we see the scarped edges of strata dipping northwards. This contrast is most observable in the gorge at Hurdwar: the strata on the two sides of the river are seen dipping in opposite directions. This phenomenon attracted the notice of Herbert and all subsequent observers.

The alteration noticed in the features of the range to the west of the Ganges is not caused by any sudden turn in the direction of the anticlinal line of flexure ; the curving is in the range itself : nor, on the other hand, is the change purely a caprice of denudation, for, together with the passage of the range to the south of the line of flexure, the strata on the north of the line are let down by a fault along the axis ; hence at Bheemgoda we find the topmost beds of clays and gravels in contact with the base of the cliffs of sandstone, and inclining gently northwards. About the Motichoor *rao* (torrent) there is a flat synclinal, the Motichoor ridge being formed of about the same beds of clay, gravel and boulders inclined to the south-west. These contrary slopes merge into the uniform northerly inclination west of Kansrao.

The Bheemgoda fault.

At present I see no reasonable escape from the conclusion, that this Bheemgoda fault must have a throw of many thousand feet, estimated by the thickness of the continuous section of the strata to the south ; these clays and gravel beds on the north of the fault are probably even higher in the series than any beds in the section to the south. If we were at liberty to consider them altogether of subsequent date, we might substitute intervening

denudation for much of the faulting, but I find no sanction for such a supposition ; these northern contact beds are certainly associated with those of Motichoor ridge, which are certainly upper Sivâlik, and, though here so little disturbed, have been in fact subject to the full effects of the disturbing forces. In proof of this assertion we find a very rare and important section in the precipitous bank of the Ganges at Raeewala : through the greater part of the cliff the stiff clays and the gravels have a steady south-westerly inclination, evidently the continuation of the arrangement in the Motichoor hill, but at the north end of the cliff the same beds are seen to curve rapidly over to a high north-easterly underlie. As bearing upon the theory of flexures there are two points to be noticed here :—in this Raeewala section we have a *normal flexure*, apparently part of a feature of some magnitude, but its fold is in the opposite direction to that of the main flexure ; and the Bheemgoda fault, along the axis of the main flexure, does not seem to conform to the axis-plane of that flexure according to the rule laid down by Prof. Rogers (op. cit., p. 897). I obtained but one short section of the actual contact ; the beds on the north were turned up sharply against it, and those on the south were also a good deal crushed, but the underlie of the junction plane was certainly slightly to southwards, or opposite to that of the axis-plane of the Sivâlik flexure. The general rule which would apply to this, as well as to other similar cases in these formations, is that *the underlie is towards the harder rock on the upthrow side,* and this would seem to be a possible consequence of the greater yielding of the younger and softer strata, which, moreover, at the time of contortion, were probably subjected to a smaller superincumbent weight. This explanation involves the continuance of the compressing action after the production of the fault.

The Chandi Devi section.

On the east of the Ganges we again find the mode of arrangement that usually obtains in the Sivâlik range; the lower beds on the south have a moderately high dip, and pass into the slightly disturbed upper beds on the north or dun side. Along

the south base an anticlinal is readily detected continuously from the Ganges to Paili Purao. The Bheemgoda fault makes no appearance on the east side of the river, the upper conglomerates being quite unbroken in front of it.

The transverse break

The interruption of direct continuity, within so short a space, of so great a fault as that at Bheemgoda, necessitates the existence of some oblique fracture along which the upheaval may die out. The abrupt change of dip on the two river banks points to this as the position of such a fracture. From the resemblance of the general sections on each side one is inclined at first to suppose the features to have been once continuous, namely, the Chandi Devi anticlinal with that at Bheemgoda, and to have been so separated by a subsequent cross fault. This is not, on the whole, the most satisfactory view: unless it keep strictly in the bed of the river there can be no such fracture, and general appearances are against it. The strata of the Motichoor synclinal seem to correspond with those facing them to the east of the Ganges. The Chandi anticlinal is certainly *representative* of that in the main Sivâlik range, and I suppose all these features of disturbance to have been contemporaneously produced.

The gorge of the Jumna.

In the gorge of the Jumna, we find again a northerly dip on the east side confronted by a southerly dip on the west, and on the same strike. The dislocation does not appear to be so great as in the Ganges, and, the river course being more winding, the opportunities for studying the details of structure are better. The anticlinal axis is easily traced along the base of the Sivâlik range. North of it, near the Jumna, the north-easterly dip of the sandstones and conglomerates is very steady, but along a narrow north and south band close to the river the beds curve rapidly round to a north-westerly dip; against this narrow transition dip the strata strike steadily from the north-west and with a high south-westerly underlie. About

half-way through the gorge the river takes a sweep to westwards, leaving on its left bank a terrace of these western rocks. Along this terrace the contrasting dips can be seen almost in contact. Towards the dun this line of fracture bends off, and seems to identify itself with an anticlinal line traceable along the southern edge of the Kyarda dun, as far as Kolur. The section on the right bank of the Jumna is a good deal more complicated than the Hurdwar section. The anticlinal of the Kyarda dun, which we have doubtfully traced into connection with the main Sivâlik anticlinal, is obscurely seen in the Batta just at its confluence with the Jumna; there appears to be more or less of faulting too; yellow boulder clays on the north are in crushed contact with sandstone and sandstone conglomerate on the south. A south-westerly dip soon becomes steady in these latter rocks, and continues so for four miles to Kalesur, in the coarser conglomerates. In the ridge south of Kalesur these same beds rise by a sharp uniclinal curve to a high north-easterly dip, thus forming the most prominent ridge of the range; it is this ridge which bends round in continuation with the crest of the range south of Kolur, thus cutting off the wedge-shaped area of the south-westerly dip. Orographically, and to some extent structurally, this area occupies a very analogous position to that of the Motichoor rao at the Ganges. At the south-east angle of these hills, next the Jumna, we have another change in the section; for a mile or more the conglomerates and sandstones dip at 80° to the southwards, the strike thus converging to that of the ridge. A culmination of this convergence seems to be reached before we lose sight of the rocks; since in the river bank, below Fyspoor, the same beds dip at 80° to the south-east. Here also, as at the Ganges, we observe a maximum of disturbance in the external portions of the range.

In the case of the Jumna there is nothing to interfere with the suggestion, that the irregularities in the actual state of disturbance in the region of the gorge may be, in a great measure, owing to the unequal

accumulation of deposits at the former river's mouth; and it may at least be asked if the river may not have had a more direct influence, if in the early stages of upheavment and contortion, the special erosion in the river course may not have had some influence in determining the position of these irregularities. Whatever view is adopted for the Jumna must be allowed its full force in the case of the gorge at Hurdwar.

Section in Noon.

I will conclude my description of the eastern region with the section in the river Noon, just below Masuri; it exemplifies fully the principal difficulties of the geology of these Sub-Himalayan rocks,—both those relating to the separation of the Sivâliks from the more recent deposits, and also the doubtfulness of separating all the rocks of the Sivâlik group, as provisionally laid down, from those of the Nahun band. The upper Noon, after it crosses the main boundary, flows obliquely through the hills of the Nahun band; near the junction there are a few hundred feet of thinner bedded sandstones, and a few clay beds, vertical, and greatly crushed; then the gorge contracts in the massive sandstone, having a dip of about 60° to north-north-east; the high dip lasts throughout, showing a great thickness of this rock, to where the river turns eastwards for a short distance, along the outer edge of the flanking hills under Suntour Gurh. Of the many streams flowing from the Masuri ridge into the dun, this is the only one in which the underlying rocks are exposed south of this limit, and the succession is certainly different from what the sections of the Nahun region would lead one to expect. Along this east and west reach of the Noon, as in a corresponding position in the other streams, clay beds are more frequent, and show an increased dip with much crushing; below them in unbroken succession, and having the same high north-north-easterly underlie, we find several hundred feet more of thick-bedded sandstones; among them bands of conglomerates are then introduced, and these gradually increase in frequency, in thickness, and in

coarseness, and at last even clays and clay-conglomerates appear in perfectly conformable sequence.

Doubtful separation of Nahun and lower Sivâlik rocks.

This section, south of Suntour Gurh, must be at least from 2 to 3,000 feet thick; its composition is so identical with a portion of the Sivâlik section that I cannot hesitate to look upon them as one and the same; and the order of succession in the Noon section shows as conclusively that the series is inverted. The question then follows, where are we to draw the line separating our Sivâlik from our Nahun groups, between these southernmost inverted clay-conglomerates and the main boundary with the slate rocks. For the map a choice had to be made, and I adopted the Nahun sections as a standard, drawing the line at the base of the hills at Suntour Gurh. To a certain extent, I believe, this to be correct. I do not think it can be doubted, that the rocks north of that line represent those north of the Markunda junction at Nahun, but I have serious doubts, whether the inverted strata in the lower reach of the Noon can be justly separated from those to the north of them. Without suggestions from other sections no one would ever think of doing so; and, moreover, any one who had come through one of the passes south of Dehra and gone on to the section of the Noon would infallibly look upon the rocks in both as the same. Some reason for a division of the section might be made out on the strength of the more vertical and crushed condition of the rocks about Suntour Gurh, I have availed myself of this pretence, but, on the other hand, this crushing is no more than generally occurs in every section of contorted rocks where the beds are thinner and more earthy. What, then, is to be the compromise as regards this boundary? I believe it will ultimately prove to be that no line drawn upon the evidence of even extreme unconformability among this great sequence of Sub-Himalayan rocks will even approximately, and in neighbouring localities, indicate corresponding deposits

There are other features in the section of the Noon which more strongly illustrate the remarks just made. We have seen in the section at Simbuwala, which is but a type of that to be found all along the range south of the dun, that the strata conformably capping the Sivâlik series are continuous with those found quite undisturbed in the dun, even up to the contact with the inner band of lignite sandstone. This fact shows the difficulty that must arise in attempting to separate Sivâlik strata from superficial deposits. In the Noon section, however, we find, at least, two distinct deposits, resting upon the edges of the inverted strata which I have just now identified as upper members of the Sivâlik series. The east and west reach of the Noon flows along the steeply scarped edge of a terrace which slopes off southwards into the general surface of the dun. The upper part of this terrace is composed of coarse and fine, more or less angular, debris of limestone and slates,—the debris of the mountain to the north. This deposit is often cemented by tufa; it attains in many places a thickness of several hundred feet, and along the flanks of the main hills reaches an elevation greater than the actual summits of the Sivâlik hills. It forms, in fact, the talus which at several places conceals all outside the older rocks. Even for this deposit I hesitate to conjecture that it has not its representative among the disturbed rocks of the Sivâlik range; for example, some of the beds on the north of the Bheemgoda fault are very similar to it in composition. Under it, in the terrace of the Noon, we find a highly contrasting deposit,—a coarse boulder-conglomerate of a light ochreous colour: the blocks are all of the harder rocks, and must for the most part belong to distant rocks. It does not exactly resemble any of the Sivâlik conglomerates that I have seen, and it has some resemblance to the mass already noticed not far from this, in the Sorna, associated with the vertical rocks of the Nahun band, near the main boundary; in this latter, however, the pebbles and blocks are, I think, more exclusively of the harder schistose

Doubtful distinction of superficial' deposits.

rocks, and are more thoroughly water-worn. On the left bank of the Noon this conglomerate caps the hill of Kungora Daen at a higher level than the top of the terrace. Seams of brown and of ochreous clay occur sparingly with this conglomerate. There is, of course, a greater probability in the case of this lower or Kungora conglomerate that it may belong to the uppermost Sivâlik deposits.

General remarks upon Noon section.

I need scarcely say how important are the bearings of the interpretation we put upon the Noon section. For a portion of it I consider there is no option but to look upon it as an inversion of Sivâlik rocks; and it may fairly be asked why should we not adopt it as the type section, instead of those in the region about Nahun, where we have independent evidence for thinking that peculiar conditions obtained. The general section (Fig. 2, p. 18) sufficiently illustrates the interpretation provisionally adopted for the outer portion of the Noon section,—the supposition that there is a geological boundary at Suntour Gurh, as shown in the map. Even this view is a very considerable modification of the Nahun sections, and there is at least equal reason for adopting it as a type. We might indeed apply this explanation to the Nahun sections themselves. We might suppose lower members of the Sivâlik series, conformable in the general section of the Sivâlik hills, turned up on edge near the Nahun junction, and there overlaid transversely by the top conglomerates, which in turn underwent contortion. The section in the Sutlej at Bubhor will fully illustrate the possibility of the case I here suppose. If, however, we are to look upon the whole section in the Noon as an inversion of the Sivâlik series, we can scarcely avoid adopting this supposition for the whole Sub-Himalayan zone, at least of the eastern region, and we must modify our views accordingly of the main boundary; it would then become a more defined locus of contortion than I have supposed it to be. The general argument I have advanced against this boundary being a great master-fault seems to me valid against the

supposition of its being a great line of uniform contortion, and thus to be the strongest argument I can make against the *primâ facie* opinion, that the Noon section is a continuous sequence of conformable strata. We shall elsewhere find analogies to strengthen this argument. I imagine the main boundary to be in kind quite like the inner Sivâlik boundary, as various as we know this to be, but in this latter case it is more easy to detect where the strata are inverted, or where in their normal order.

The western region.

In the eastern region the difficulty was the indication of any precise division in a series of very similar deposits, apparently conformable and transitional in one zone and irregularly but strongly unconformable in another. The same puzzle will occasionally occur in the western region; but here the chief difficulty is to indicate any defined break in a great series, the extreme members of which are very dissimilar in many important respects. The top rocks have a newer aspect, and the bottom ones a more ancient, than in the sections to the east. In the Guggur on the east, and in the Ravee on the west, there are seen two belts of rock which no one could hesitate in separating; yet in examining the intermediate area one would include the greater portion of it with one or with the other of these belts, according to the direction in which one proceeded. If examined from the south-east most would be classed as a lower group, and from the north-west the outer band seems to spread over well nigh all. When the boundary comes to be traced, if indeed it ever can be,—if any continuous physical break in the newer Sub-Himalayan period exists in the greater part of this western area,—the middle group will appear as strips occupying the long narrow ridges which traverse the region more or less continuously in a north-west, south-east direction. In several cases these ridges disappear to the north-west, the lower rocks thus becoming enveloped in the upper.

General composition of middle group;

The composition of the middle group from the Guggur westwards is very different from what we have seen in the Nahun rocks, and far less simple. We scarcely even find a lithological representative of the lignite sandstone, unless it be among the doubtful rocks of the region of the Beas. The rocks which, north of the Pinjore valley, form an intermediate band between the Sivâliks and the Subathu group, have a closer resemblance to the latter than to the former; the thick-bedded sandstones are of a dark colour, often coarse, and are well hardened; beds of clay are very frequent. The most notable difference, however, is that in the Sutlej we find the middle group surmounted by a great thickness of conglomerates that cannot be confounded with those capping the younger group to the south. The outer rocks of this great series of deposits, and which we can, within general limits, continue to distinguish as Sivâlik, consist as before of massive conglomerates, coarse and fine, alternating with, and overlying, thick beds of sand and clay.

and of Sivâlik group.

Middle group of Sutlej area.

In the Mungrud the whole middle band is about a quarter of a mile broad; and, the strata being nearly vertical, this also represents their thickness on this section. In the Sursulla, near Kalka, the belt is nearly two miles wide; for the greater portion of it there is a broken section of coarse gritty clays, and red and purple, hard, earthy sandstone, coarse and fine; the dip is not very steady, varying from east 15° north to 50° north; it is high throughout. For a few hundred feet next the outer boundary, a massive, clear gray sandstone shows itself, having an opposite underlie to the rest of the section, being also greatly crushed; this rock is not exposed in every section, there is none of it in the Mungrud, but it is noteworthy as being possibly the only true representative of Nahun rocks here, the rest belonging to a distinct period of formation, and which a more minute study may separate as a fourth

Sursulla.

? a fourth group.

division of the series, intervening between the Nahun group (bottom Sivâlik) and the Subathu group.

Between Kalka, where the group consists of but a narrow band forming a low, flanking ridge, and the Sutlej, where it is sixteen miles wide and forms several ridges separated by well-defined fissures, there is a complicated knot of hills east and north-east of Nalagurh, in which the flexures and fissures of the region to the north-west take their rise. The irregularities of strike in this area can only be reduced to some order by tracing back into it the leading flexures as developed to the north-west, the complexity being apparently due to the mingled effects of the general disturbing force, and the influence upon it of the oblique surface of resistance of the Lower Himalayan mountain-mass : the lines, which in the open area between the Sutlej and the Beas have a remarkably regular general run to south 35° to 40° east, become deflected more to the south in the vicinity of the higher hills. A short way to the east of the Sutlej, along the road from Roopur to Belaspur, there are but two distinct ridges of hills. The outer one is formed of a principal anticlinal bend, occupying the crest of the ridge, but there are several minor features which are more distinguished elsewhere. There is a well-marked longitudinal synclinal fold at the lower end of the Kundulu lake; it curves round into the projection of the range over Nalagurh on the east, where it flattens and vanishes. Between the lake and the crest there is a wave in the general west-south-west dip, indicating an anticlinal and synclinal fold; these are the beginnings of the deep flexures to the north-west. The rocks here are of the harder, lower type, and clays are abundant. Along the crest the dip turns over abruptly at the main anticlinal, and the great unbroken sheets of rock, standing up nearly vertically, give a very rugged aspect to the north side of the ridge ; this is a very common feature in these hills. The rocks here are very thick, coarsish, softish sandstones.

Knot of hills east of Nalagurh.

Kundulu and Belaspoor section.

The dip remains steady to the same direction, lowering to 50° at the Gumber, the upper portion of the section being of alternating conglomerates, sands, and clays. The valley of the Gumber is cut along the strike of these rocks. In the ridge, rising abruptly on the north of the Gumber, we come again suddenly on the oldest type of rock,—hard purple sandstones, and red clays. Throughout the ridge they are more or less vertical, underlying now to one side, now to the other, but becoming steady to a north-easterly underlie in the valley of the Gumrola, where we again pass, without discernible demarcation, into the same series of softish sandstones, clays, and conglomerates. The coarsest varieties of the latter are in contact with the limestones and slates along the main boundary, where they dip as usual at a high angle towards the contact.

The Gumber fault.

There can scarcely be any question as to the existence of a great fault along the Gumber: this feature is traceable, with but little variation of character, past Jualamuki to the Ravee, near Bussowlee Ghât. In a south-easterly direction it is very distinctly defined as far as the bifurcation of the river; here the feature in most direct continuation with it is a synclinal axis, along which a ridge is soon developed, striking into the main boundary at the village of Chandi, but orographically and structurally the lower Gumber feature is represented in a parallel direction, slightly shifted to the south-west, by the valleys of the Koaj and the Ballud. At the low gap separating these two streams, the thick, coarse, soft sandstones of the outer ridge—the same rocks as noted on the ridge south of the Gumber—underlie at a high angle to east-north-east, and thus seem to pass beneath the thin, hard sandstones and red clays of the inner ridge, the dip being about the same in both. The coarse sandstones can be traced close up to the main boundary south of Khudi; and thus the well-defined belt of rocks north-east of the Gumber, at the Sutlej, gradually dies out against the main lower Himalayan boundary.

Nothing that I have seen in these hills has more impressed upon me the grand scale of these natural operations than the regularity of the great flexures and fissures of the Sub-Himalayan strata, and especially their general independence of the neighbouring mountain contour, unless when brought within its immediate passive influence.

Although the general structural features are so continuous from the Sutlej to the south-eastwards, there are very important lithological changes in the sections. Between Budi and Khudi there are only the few beds of coarsish, softish sandstone already mentioned, near the latter place, to represent the bands which near the Sutlej must be 6 or 8,000 feet thick. In the intermediate section, crossed between Nalagurh and Erki, the same beds are more fully represented north of Ramgurh, and again about Saihutti, but still only feebly, and there are yet no conglomerates among the topmost beds; next the main boundary north of Saihutti there are just a few strings of pebbles. There can, I think, be no doubt in considering the bands of the Gumrola and the Gumber as one and the same formation; and the conglomerates seem to belong to the soft coarse sandstones with which they are so closely associated. I cannot but think that both these rocks will yet be separated from the more ancient looking beds which protrude from beneath them; still I am unable to make the distinction on the grounds of contrasting degrees of disturbance; we will see that these very bands of the Gumber and Gumrola expand into the duns and plateaus of the Kangra district, and there flatten out into a more or less horizontal position, but there, as here, they are found turned on end, and inverted, with the older rocks, in the vicinity of the lines of flexure.

The Belaspoor conglomerates;

In the composition of these conglomerates about Belaspur there are some very interesting peculiarities; recollecting the intimate relation between the composition of the Sivâlik conglomerates of the eastern region, and the position of

their peculiar composition.

the great rivers, one is surprised to find no such relation here, the Sutlej being at present the mightiest of these mountain torrents. Where the conglomerate beds intersect the Sutlej, about four miles north of Belaspur, all the large boulders are of the hard purple sandstones of the Subathu group, and even the softer, fossiliferous, nummulitic strata are represented among the debris. We find on the spot the most complete means of comparison; over the whole valley of Belaspur, and capping hills to a height of 2 to 300 feet, there is a coarse diluvial boulder conglomerate, evidently the work of the Sutlej at some remote period, the boulders being thoroughly water-worn, and composed of siliceous, metamorphic rocks. The first idea that suggests itself in explanation of the difficulty is that these deposits are of much older date, and that denudation had not at that time carved out the actual drainage system so deeply that the more distant debris could reach so far. This notion is strengthened when we see that the influence of the great rivers as described to the east is not peculiar to that region: the Sivâlik conglomerates at Bubhor are most distinctly traceable to the Sutlej in its actual position. The contrasting composition remains, no doubt, in proof of the different, and of course, greater age of the Belaspur conglomerates as compared with those at Bubhor, but a further comparison compels us to modify the generality of the inference, and to attach all the interest of the peculiarity to the special history of the Sutlej. The conglomeritic bands of the Gumber and the Gumrola are continuously traceable to the Beas, but we do not find there the same peculiarities. About Likwanu, at the head of the Sher Khud, even south of the present watershed between the Sutlej and the Beas, the crushed and highly inclined conglomerates, which there is no shadow of reason for thinking of different age to those at Belaspur, contain only debris of metamorphic and granitic rocks. This fact explains the somewhat paradoxical assertion, previously made, that the classification of these rocks would depend upon the direction in which the observer

proceeded: in the section of the Sutlej the necessarily great difference in age between the conglomerates of Belaspur and of Bubhor is at once apparent, and would fairly be extended to the representative beds to the north-west, irrespective of the failure of the original distinguishing characters; whereas, in coming from the north-west one would consider all the rocks of the Kangra duns as Sivâlik, till brought to a check by the section of the Sutlej. I do not see any way out of the dilemma, but I am aware that my study of this large area has been after all superficial, and inadequate to niceties of classification.

There are some very interesting questions connected with the portion of middle Sub-Himalayan rocks we have just examined between Kalka and the Sutlej. Is the fact of the greater proportion of the lower beds in this area, and the gradual disappearance of the upper beds to the south-east, due entirely to the greater contortion and consequent elevation and denudation of the upper beds, or does it involve elevation independent of contortion, and if so, was this prior to or subsequent to the deposition of the Belaspur beds? The result is one of the same kind as I have, in the case of the Subathu group, taken to prove a general easterly upheaval of the area. A close examination of the mode of thinning out of the top beds in the valleys of the Gumber and Gumrola would help to solve the problem; but the full solution of it must await the discovery of fossils by which the relative ages of these doubtful middle bands may be fixed. It has occurred to me as possible that the bottom beds of the Sutlej area may be the records of at least a part of the long period of denudation which I suppose to have intervened between the Subathu and the Nahun groups of the eastern region,—they may be the very debris of that denudation. Or once more I will ask the question, may these bottom rocks of the Sutlej area not belong to the Subathu group,—may not the difference of composition, which is after all not very great, be accounted for by local conditions of the time? May not the ridge of limestone, now separating the two areas, which I

believe to have existed more or less as such upon the sea-bottom of the Subathu period, have produced the difference we observe in the rocks? The gravest objection to such a supposition is the persistent absence of any sign of the easily recognized bottom nummulitic beds, no matter how great the upheaval, or of any of the subjacent black slates, no matter how great the faulting or crushing.

Sivâliks of Pinjore and Una :

The commencement of the Pinjore dun is structurally very analogous to what we have seen that of the Kyarda dun to be. Massive bands of boulder conglomerate are introduced at the top of the Sivâlik group capping the range in the Basgati summits, where they have the same moderate dip as the underlying strata. The boundary of the Nahun group takes a sudden bend towards the debouchure of the Guggur, and the conglomerate slopes down along it into the dun, forming on the right bank of the river a perfectly undisturbed valley-deposit resting against the steep hill of the middle rocks.

local conglomerates ;

These Basgati conglomerates are composed of debris of the Subathu sandstones, and have probably been deposited by the Guggur in an early stage of its existence. This river passes through the low outer range by a wide open gorge south of Kalka ; on both sides the conglomerates have a dip of 30° to north-east, and, as before, the same beds appear in the dun at a short distance, and quite undisturbed, at the confluence of the Sursulla and Guggur. The contrast is more striking than in any examples I could

important junction in the Sursulla ;

give in the Dehra dun, and it requires the most distinct evidence to make any one believe that these undisturbed beds are not simply a dun deposit, the fact of lithological resemblance being manifestly of very little weight. This evidence, however, is at hand, and, as if to suit the occasion, it is the most satisfactory of any that I have seen. In continuing up the Sursulla, these boulder beds last undisturbed for some miles ; but within half a mile of the inner boundary they have an equally steady dip of 15° towards

the junction, where they are in vertical and crushed contact with the sandstones of the older group.

The outermost range of hills is in this western region much flatter than to the east. This is the more apparent in the eastern portion of the Pinjore dun, on account of the immediate proximity of the Lower Himalaya, and it is interesting to observe that this proximity seems to have exercised no influence upon the state of disturbance of the youngest rocks, which is if anything less here than elsewhere: I am not prepared to offer any positive explanation of the coincidence. The diminished prominence of the Sivâlik range seems to be in some measure due to change in composition: the sandstones are more earthy, and much softer than to the east of the Markunda, and the alternations of clay continue to be more frequent. It is only of the Sivâliks of this region that we can say that their strata are undistinguishable from those of the plains. The passage of the Sutlej through the range at Roopur is a wide alluvial valley. In two sections that I made of the range beyond,—one outside Una, and the other near Hoshiarpur—the flat anticlinal flexure is well defined, and still of the normal type, with the lesser slope towards the dun. This ridge, which is more or less continuous with the Sivâlik range of Dehra, does not extend beyond the Beas; the second zone there becomes the outermost.

Little disturbed near the Lower Himalaya.

There is a well-raised plateau of what appear to be upper Sivâlik conglomerates in the dun between Nalagurh and Kirithpur, against which the Sutlej turns southward; these deposits reach well up to the foot of the hills under Kundulu. Immediately to the west of this, we find a great change in the arrangement of the rocks, reminding one of the Noon section as compared with that at Simbuwala. Near Nandpur, just north of Nanowal, the very strata of the dun,—kunkury, calcareous clays, and sands, with irregular patches

Inner junction.

Nandpur.

hardened by tufa, and occasional strings of small boulders,—turn up within a space of 100 feet, from being horizontal to a dip of over 80° to south-30°-west; these beds pass into and overlie a great thickness of massive gray soft sandstone, with here and there a good sized pebble occurring in it. The section continues most steady to near Kot, giving at least 5,000 feet of the upper rocks. Here, at the base of Naina Devi, the strata being all but vertical, there is a sudden change to dirty red clays, and yellowish brown sandstones, like the rocks north-east of Nalagurh. In these the opposite underlie soon declares itself, and decreases up the ridge. Passing on to Bubhor

Bubhor.

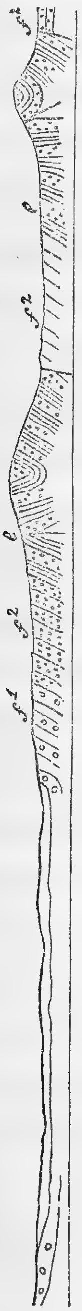
we find the same section, but the upper beds here consist of massive conglomerates, with an increased thickness of fully 2,000 feet. To complete the analogy with the Noon we find here other boulder conglomerates lying on the edges of these at a considerable height above the Sutlej. Further on still, near Una, we again find the yellow, marly clays of the dun turned up with a south-westerly dip, at first so low as 40°, but rapidly increasing nearly

Una.

to the vertical: conglomerates are here again subordinate, and the passage into the pebbly gray sandstones is rapid, but alternating and quite conformable; here, moreover, there appears to be a transition between these and the brown earthy sandstones and red clays of which the Naina Devi ridge is formed. The mode of occurrence of the Bubhor conglomerates leaves very little doubt that they are not a remnant of a widespread boulder-deposit, but that it was formed by the Sutlej, having its embouchure at or about its present position, and this rock, with its associated beds, seems to be transitional into the gray pebbly sandstones. Yet this latter rock is, I believe, the same as occurs most extensively to the north of these sections, occupying the duns of the Kangra district, being there, as has already been stated, apparently transitional with the Belaspur conglomerates; it is well seen in the valley of the Sutlej, on the north of this

FIG. 17.

S. W. N. E.



SIVALIK HILLS. UNA DUN. NAINA DEVI RIDGE. SOLA-SINGHEE RIDGE.

Kot anticlinal. Koseree fault. Budsur fault.

Section at Una. $f.^1$ Conglomeritic Sivâliks. $f.^2$ Gray pebbly sandstone. *e.* Brown and red sandstones and clays.

narrow ridge of Naina Devi as far up as Fungwanu, but from Belaspur to Koseree I found no remnant of the Bubhor conglomerate.

However regular the ridges of this region may be in direction, their details of structure are exceedingly complicated. The section from Una to Budsur (Fig. 17) affords complete exemplification of these intricacies, which are of the same kind elsewhere. The two ridges of Naina Devi and Sola-Singhee seem to have grown out of the broader and less defined ridge over Kundulu. They are both formed along synclinal axes, the dip being inwards on each flank, and the rocks of both are certainly the lowest of the section, the softer, newer rocks appearing in the valleys and plains. In the former position, as in the Sutlej valley about Koseree, the phenomenon reminds one strongly of the case of the nummulitic outliers between the Krol and the Boj, yet the parallel does not seem complete enough to admit of our adopting the same mode of explanation, namely, the pre-existence of the ridges of older rocks, or at least not to nearly the same extent; the evidence here is strongly in favour of faulting, and of folded flexures. In the sections of the south flank of the first ridge, under Naina Devi and in the Sutlej, we have seen a sharp anticlinal bend, with apparently some faulting; in the Una section to the west, this anticlinal axis

The Una section.

encroaches upon the ridge ; from where it reaches the crest the ridge dies out rapidly, the dip decreasing, and the upper rocks, or at least a portion of them (the gray sandstones), spread round the sloping end of the ridge.

Koseree fault.

On the north-east side of the ridge, from near the head of the valley at Fungwanu, there is a well-marked fault; the gray sandstone is found dipping against, and apparently under the synclinal ridge. This main fault does not extend to the end of the Naina Devi ridge; it curves slightly to the north, and along it a new ridge rises, having at first a simple south-westerly dip, but it too bends off to the west, and terminates north of Chouki, like the Naina Devi ridge, in a semi-circle of diverging dips of the upper rocks. North-east of the Koseree fault, in the ridge of Sola-Singhee*, we have a modified repetition of the Naina Devi ridge. Close to the fault the upper rocks are sometimes nearly flat, but generally inclined at a high angle towards it, and sometimes again at a high angle from it: the fault occurs, I believe, approximately along a synclinal flexure, and thus these conditions of dip depend upon the amount of throw at any point. The south-westerly dip gradually increases to the vertical, and so passes to an opposite underlie (the ridge generally com-

Sola-Singhee ridge.

mences about this point of the section), and so to the crest of the ridge; the section throughout has been geologically a descending one, or at least the lowest rocks occur on the ridge, though not perhaps at the top. There is no way of explaining such a section but by inversion,—a folded flexure of which, the axis-plane, underlies to the north-east. Along the north-east base of this ridge also there is a well marked fault, passing close to Budsur. I obtained no

Koseree and Budsur faults.

satisfactory observation of the underlie of these two faults of Koseree and of Budsur; if anything out of the vertical position it seemed to me to be towards the ridges.

* As these ridges are for the most part without names, I have, as a rule, given them the names of temples or forts built on their crests.

There can be no doubt however that the downthrow is on the north-east, *i. e.*, with, not against, the direction of the axis-plane of the flexures. It were premature at present to insist upon the amount of throw of these faults; if we are to conclude that all these deposits once covered the whole area to an equal depth, the throw must be enormous, but it seems possible that these flexures may have been more or less formed prior to the completion of the series, and hence the irregularities of present position may have been to some extent *ab origine*. The fact, however, already mentioned in the Hurdwar section, is equally applicable here,—the newest rocks, that are disturbed at all, seem to have undergone as much disturbance as the others. In the mode of termination of the Naina Devi ridge we have examples, though somewhat irregular, of the passage of the same contortion from being *folded* to being *normal* and *symmetrical* flexures.

Extension to the Ravee of the Naina Devi flexure.

Before passing on to the north-east I will rapidly notice the extension of this second zone up to the Ravee. The continuation of the Koseree fault seems to coincide with a sharp synclinal fold passing obliquely along the north-east point of the Purwain or Gungot ridge; and further to the north-west it may correspond with the synclinal or the uniclinal curve of the strata in the dun beyond the Beas. The Purwain ridge is the representative, and, in a manner, the continuation of the Naina Devi ridge, but the features are altogether changed; it is a broad flat ridge of the ordinary Sivâlik type. A low north-easterly dip prevails throughout, and thick boulder conglomerates reach up to the crest, sandstones and clays cropping out along the south-western slopes to the Una dun. There is probably a sharp double curve concealed beneath the dun, for conglomerates, though less coarse than those on Purwain, come in again on the inner slopes of the outermost range. In the gorge of the Beas, through the Purwain ridge, there are excellent sections, showing rather complicated disturbance, which we may reasonably infer to be local; the rocks are the

gray pebbly sandstones, and the bottom beds of the conglomerates. West of the Beas this range becomes the outermost zone of hills. It too flattens out into a low expanse of hills, east of Puthankot, and so comes to an end before reaching the Ravee. At Tangoo hill, two miles south of Puthankot, and the most westerly point of the Purwain ridge, a deep cut has been made through the ridge to divert the course of the Chukkee stream, showing an excellent section of brown clays, and gray gravel with small boulders, having a very steady dip of 30° to west. In the low hills all round very similar strata are found, showing little or no disturbance, and probably belonging to the recent plains' deposits, overlapping a denuded surface of Sivâlik strata; the many instances, however, we have seen in the Sivâlik rocks of sudden change from original horizontal position to one of extreme displacement should make us cautious in interpreting observations of this kind.

Extension of the Sola-Singhee flexure.

From the Sutlej nearly to the Beas the whole compression of the band between the Gumber fault and the Koseree fault is concentrated in the complicated, faulted flexure of the Sola-Singhee ridge. Beyond this ridge, in both directions, the Budsur fault passes into an anticlinal axis. On the south-east it is in continuation with the axis of the ridge north of Kundulu; and to the north-west it passes into the anticlinal axis, which is first distinctly seen in the ridges between Jualamuki and Deihreh, whence it can be followed without interruption to the Ravee, where it appears along the north base of the Dulla ridge; at almost every point there is more or less of faulting, with a northerly down-throw; and on the south there is a general tendency to a recurrence of high opposing dips, thus retaining a considerable resemblance to the section at Budsur. At Nurpur there is a strange variation in this feature, appearing on the map as a regular southerly sweep of the line. The beds on the north of the axis become extended, curving over so as to complete half the arch of the anticlinal. It is on the flat back of this arch that the town and fort of Nurpur are

built. In the steeply scarped slopes on the south the reverse dip appears nearly vertical. One cannot but feel astonishment at the close proximity of such gentle unbroken curving to such intense crushing; a closer examination of the locality might discover evidence of unconformability.

In this neighbourhood I noticed a fact that may turn to some account. In the sections of the Chukkee, of the Nurpur stream near Mudunpur, and of the stream south of Kotleh, in about the same position in each, and thus forming a continuous line in the zone, there may be seen an abrupt change in the amount of dip from 20° or 30° in younger rocks to 60° or 70° in those below them. There is no break or strain, and the sections were not deep enough to show distinct unconformability. It appears to me as if the lower beds may have been considerably tilted before the others were laid over them. At, and west of, the Ravee this zone of Sola-Singhee forms the outermost range.

The Nadaon dun.

The Nadaon dun, the undulating plateau between the Budsur fault and the Jualamuki ridge, is occupied by gray pebbly sandstone and the lower beds of the conglomerates, dipping at a low angle, and apparently without any very definite order. In its north-west portion there are two subsidiary flexures that are well defined for some distance. North of Deihreh the main anticlinal bifurcates, apparently where the Budsur fault begins to be decided; a flat anticlinal bends off towards Jualamuki, and continues for many miles close along the base of this ridge. Beginning close to the angle of the bifurcation a sharp synclinal fold continues, not far from the Budsur fault, to as far as Sola-Singhee.

The Gumber fault.

The Gumber fault is traceable continuously to the Ravee, but it is no where so well marked as in the Gumber valley. There can always be discerned a ridge of the older rocks, passing by gentle slopes into the higher rocks on the north-east, always more or less scarped on the south-east, and

with younger rocks generally dipping towards it. At some places to the north-west, as at Kotleh, the fault is very well seen. Sometimes the whole feature is very obscure. The most puzzling section of it is in the Bangunga, south of Kangra; the older strata, with the appearance of perfect conformability, overlie the younger, the dip not being more than 40°. There is some collateral evidence to support the opinion that there is a deep line of disturbance in this position. At the famous shrine of Jualamuki an inflammable gas perpetually issues from the rock (unless indeed it be cooked by the priests below ground); and at Lunsu, below Dalhousie, there is a hot medicinal spring on this same line of disturbance. There is at least one marked difference between this line of fissure and those we have noticed to the south-west; here the up-throw is on the north-east side, and the underlie of the contact is, as usual in these faults, towards the older rock. The many cases of doubtful superposition and other complications along this line are not explicable by a simple fault; there must be a folded flexure with the fissure chiefly in the synclinal.

The Kangra plateau.

The area to the north-east of the Gumber line of flexure is for the most part a rugged plateau, or rather a maze of ravines cut out of soft gray sandstone and overlying conglomerates, which lie in a more or less horizontal position; the general surface of the irregular ridges ranges between 2,500 and 3,000 feet in elevation. Along the base of the Dhaoladhar the sandstone is more or less eroded and covered by superficial deposits, thus forming the disconnected areas known under the general name of the Kangra dun.

The more marked lines of disturbance inside the Gumber line of flexure conform to the curved boundary of the high mountain district, but in all structural details they resemble the more regular flexures of the outer zones. The most important of these lines is the junction of the gray sandstones and the conglomerates with the inner zone of lower

or middle Sub-Himalayan rocks,—the continuation, in fact, of the line which, to the east of the Sutlej, forms the main lower Himalayan boundary. It is not a continuous line in the region of the Beas, and it is interesting to see how the newer rocks lap across it in a manner exactly similar to that in which the gray sandstones of the Bubhor section laps round the point of the ridge north of Una. Towards the upper end of the Sher khud soft gray conglomeritic sandstones have a low inclination to eastwards on the west bank of the river, and on the east side we find deep red clays and hard purple sandstones, with a high dip in the same direction. Further up, about Dubrog, the contact is obscurely seen, and it is rather puzzling; conglomerates of the coarsest description, containing well rounded boulders of quartzite and of granitic rocks two feet in diameter, and which are shivered to splinters in place by the crushing action, are found jumbled together with the red rocks, and not exclusively along a definite vertical band,—I found the conglomerate *in situ* 100 yards due east of a section of the red rocks. Crossing the watershed to the next stream on the north, the younger rocks rapidly assume a high westerly underlie, and then curve in a most regular manner round the point of the ridge separating the Sher from the Suin, forming a semi-circular diverging dip, and a sloping anticlinal axis on the ridge, but they do not extend far either in the valley or on the ridge, older looking rocks cropping up from beneath them. East of the Suin another fissure separates them from the main area of the inner zone. Thus terminates the line of boundary which has so often been noticed already. It may perhaps be questioned whether the feature (in its faulted character) really dies out here, or whether it be only covered up, but there seems very little presumption in favour of the latter supposition,—the structure displayed by the younger rocks corresponds very exactly with the production of a fissure or slip of some extent in that position,

The Belaspur fault;

its termination.

and there is no warrant for going beyond this, unless indeed to satisfy a theory.

The Puthiar promontory.

It is curious to notice, about thirty miles off, on the other side of this wide bay of the newer rocks, a very similar termination to the corresponding boundary below the Dhaoladhar. The ridge of Puthiar is formed of the lower beds. On its south-west side, between it and the Jarait hills, the conglomerates are vertical, and even inverted along the junction, both rocks having a south-easterly strike. Round the point, towards Burwarneh, the conglomerates are continuous, and stretch on the north-east side nearly to the inner Sub-Himalayan boundary, having a high dip from the Puthiar ridge. I noticed that the conglomerates in this position are remarkable for the local character of their pebbles, sub-angular fragments of the pink limestone of the range close by, with larger blocks of the brownish gray sandstone that intervenes, being the chief ingredients. In the conglomerate on the outside of the ridge the blocks are larger and more rounded; there is too a considerable admixture of the hard inner rocks. These peculiarities suggest the existence of the Puthiar ridge as a promontory in the area of deposition of the younger rocks, and consequently that the feature, as we now see it, is not solely the result of disturbance subsequent to that period. The same inference may be extended to the corresponding feature towards the Sutlej; it is but a confirmation of the opinion we had to come to in examining the eastern region—that the outer rocks were formed upon an eroded surface of preceding deposits.

West of Dhurmsala.

West of Dhurmsala the upper portion of this Kangra zone is not so denuded and covered over as along the duns, and we find grand sections showing an enormous development of the conglomerates. The circumstance is manifestly connected with the presence of conditions very similar to those now existing, these conglomerates containing the debris of all the rocks now exposed in the lofty range that rises immediately to the north,—of the trap, of the lime-

stone, and even of the brownish gray sandstone of the narrow band of older Sub-Himalayan rocks. Yet we find these same conglomerates conforming most regularly to a structure that seems to be coeval with the formation of the range, it being as distinctly marked in the youngest as in the oldest rocks; for several miles up the gorge of the Ravee, the conglomerates underlie at a high angle to east 15° south. We here only find the bottom pebbly beds, along the edge of the river, the upper coarser beds having no doubt been removed by denudation; at a short distance off at least, across the river, the same rocks have a moderate dip to the north-north-east, and the conglomerates are well developed.

The innermost zone;

There still remain some observations of much interest to be noticed regarding the innermost zone. In the ridge at Sid the rocks resemble those of the section south of Khudi as much as they do anything in the Subathu group; but the newest rocks are here, as in the other zones, to be found along the inner boundary. At Mundi there are some thick softish light gray sandstones, undistinguishable from the Sivâlik rock. It is only however at the very head of this wide recess of the Sub-Himalayan area that the highest beds of this zone are preserved. From a short way north of Drang to about Haurbaug conglomerates and clays are the top rocks of the section.

its conglomerates near the Beas;

In the hill at Sih we find the best sections of the uppermost beds; they are very massive banks of coarse breccia rather than conglomerate, being composed of large and small angular debris of the cherty limestone and of the pink sandstone occurring at the contact close by, in the outermost band of the Lower Himalayan rocks. These beds dip at 40° to eastwards, and they overlie thick strata of clay and of fine sandstone-conglomerate, in which the debris is chiefly of the hard, inner rocks, and well rounded, but containing in the upper beds a mixture of sub-angular pebbles of the limestone, thus in a manner graduating into the breccias at top. The peculiarly local character of these beds is very remarkable, and even requires some

special mode of formation. There is one strange fact common to all the coarser deposits here; they contain no trappean debris, or at least so rarely that I happened to observe none, although trap rocks at present largely predominate in the ridge immediately above, and coarse trappean debris so prevails in the actual talus overlying these conglomerates as to be mistakeable for trap *in situ*. In the conglomerates of the succeeding zone of Sub-Himalayan rocks, described in the last few paragraphs, debris of this same band of trappean rock is common. We must at least suppose that at the time of formation of these innermost conglomerates the fringing belt of limestone, sandstone, and slaty shales was much more developed than now; but we are scarcely yet prepared to admit that the introduction of the trap was subsequent to the deposition of these conglomerates at Sih. It may be well to mention too that I noticed no debris of pre-existing Sub-Himalayan rocks. The well rounded pebbles of the lower beds must have come from the inner rocks of the Himalayan series, and, we may perhaps infer, were brought down the gorge of the Beas, but there is no connection at present very manifest between these beds and that river; the upper beds have been denuded from the position of the actual gorge. These Sih conglomerates are quite cut off from any similar deposits in the other Sub-Himalayan zones; thus in the Beijnath section we again find only the harder and deeply coloured underlying beds. The position and the peculiarities we have noticed in this isolated patch of rocks render them specially interesting; the special facts seem to point to their being totally distinct from all the similar deposits to the west and south, yet in general aspect these strata form as great a contrast with the other rocks of this zone as do those outer conglomerates which are so often seen to contain their debris.

at and west of Dhurmsala.

At Dhurmsala the rocks of this zone are well exposed, exhibiting an intermediate and doubtful type as described in the areas east of the Sutlej. To the west, however, the zone is very subordinate, being scarcely recognizable at places, as in

the sections of the several feeders of the Chukkee and of the Dairhh. In fact, though I have represented the zone as continuous on the map, I think that the soft, reddish-brown sandstones and clays, with some bands of conglomerates (containing Sub-Himalayan debris), forming the narrow band separating the massive conglomerates from the trappean rocks, between Sihunta and Choari, belong to the same group as the massive conglomerates themselves. On Buklo ridge we have again a fuller section of this inner band of lower rocks, but it might well be asserted that they are only the same beds as are found regularly underlying the conglomerates in the sections to the south. The case here is in fact completely analogous to that already discussed between the Nahun and the Sivâlik zones of the eastern regions.

The point of most evident importance in this western district is the determination of the degree of equivalence of the similar beds in the uppermost portion of the successive zones. The relation of the top beds to the underlying strata, is a question common to the whole Sub-Himalayan area. The successive disappearance of the two outermost ranges to the north-west is of considerable interest. It is not quite apparent, moreover, whether denudation may not be the chief cause of this; there is certainly no decrease of disturbing energy in the section at Hoshiyarpur as compared with that at Pinjore. Such a decrease is very marked indeed in the second zone, between the sections at Una and at Gungot, but until the precise relations of the upper Sub-Himalayan groups in this region be more closely made out this comparison is not admissible.

CHAPTER V.—*Post-Sivâlik Deposits.*

Well-marked separation of Sivâlik and Gangetic rocks.

I HAVE already had to notice undisturbed deposits covering vertical strata to an inconsiderable thickness, yet (doubtfully) connected with the upper Sivâlik period. The great formation of *later* date with which one might seek to co-ordinate such deposits chronologically is the Gangetic formation. Between the Sivâlik strata and those of the Gangetic plains there is the most decided separation ; there is no approach to a shading off of disturbance, merging the one into the other. We have seen this to be very marked in the eastern regions, in the sections of the Ganges and the Jumna, where the most southern Sivâlik rocks have a nearly vertical dip. In the western district the general contrast between the formations is not quite so striking at the contact, but the argument is confirmed by the fact that the state of disturbance of the outermost range is as great as that of the range inside it : for instance, in the section between Deihreh and Hoshiyarpur, the Purwain ridge is composed of probably the same strata as those of the outer ridge ; be this, however, as it may, the highest underlie found in the whole section is along the edge of the plains, where it is 70° to southwards. Although little evidence exists in the narrow band of Sivâlik rocks now exposed along the outer fringe of the mountain-region of a diminishing intensity of disturbance in a south-westerly direction, we may, I suppose, presume that such actually occurs in the extension of these strata beneath the Gangetic formation.

Limits of Gangetic deposits.

The great accumulation of boulder gravel which everywhere covers the south base of the Sivâliks, can scarcely be looked upon as belonging to the group of deposits I here speak of as the Gangetic formation. These conglomerate

banks are annually being enlarged by the torrents from the Sivâliks, whereas the regular plains'-deposits are deeply eroded by these same torrents in the lower part of their course, and by the great rivers. Whether these more regular strata were laid down *in* water, in a basin of deposition, after the manner usually supposed, or only *by* water, by the unaided operation of river action, as has lately been maintained by Mr. Ferguson (Quar. Jour. Geol. Soc., London, Vol. XIX., p. 321), it is evident that long since a period of erosion had set in in these higher regions of the Gangetic plains. Such being the case, it would be interesting to find out what limits the deposit may have formerly attained. Does that flat talus of coarse debris that is still in process of formation along the base of the Sivâlik range rest upon and pass continuously into the topmost beds of the Gangetic formation, or can it overlie a denuded surface of these strata ? I strongly incline to the former supposition. Evidence on the other side is altogether wanting. Had the Gangetic formation ever been much thicker, and thus necessarily extended more or less over the Sivâlik hills, the denudation which reduced the level of the main area could scarcely have spared any outlying remnants. Along the south front of the Sivâliks I have not detected any elevated patch of superficial deposits that might not be due to some petty local cause, such as the temporary formation of a lake. About the openings of the great river gorges we sometimes find, close to the Sivâlik hills, strata that do not belong to the talus-deposits of these hills. The low flat mounds near Hurdwar are formed by a stratum of stiff clay covering one of coarse boulders, resting on a basis of the highly inclined Sivâlik conglomerates, this basis being fully ten feet higher than the present full-flood level of the river.

In connection with this subject, and especially with reference to the discussion raised by Mr. Ferguson, Dr. Hooker's observations at the base of the Sikkim Himalaya are of great interest. The conditions there are very different from what we have seen to the north-west. In speaking

of the Terai, at p. 378, Vol I., of his "Himalayan Journals," Dr. Hooker says: "The gravel beds extend uninterruptedly upon the plains for fully twenty miles south of the Sikkim mountains, the gravel becoming smaller as the distance increases." "Throughout its breadth this formation is conspicuously cut into flat-topped terraces, flanking the spurs of the mountains, at elevations varying from 250 to 1,000 feet above the sea." "In many places, especially along the banks of the great streams, the gravel is smaller, obscurely interstratified with sand, and the flattened pebbles overlap rudely, in a manner characteristic of the effects of running water; but such is not the case with the main body of the deposit, which is unstratified and much coarser. The alluvium of the Gangetic valley is both interstratified with the gravel, and passes into it, and was no doubt deposited in deep water, whilst the coarser matter was accumulating at the foot of the mountains."

Gangetic, compared with the superficial deposits of the duns.

If the opinion be adopted that the strata of the plains have not been much reduced by denudation, our previous inference regarding the superficial deposits of the duns is strengthened, that they, for the most part, belong to a more remote period of formation than the deposits of the plains, and are more closely connected with the Sivâlik period. The boulder-conglomerate, and the other undisturbed deposits about Kungora, in the Noon section, are more raised above the plains than the highest point of these is above the sea-level, and I have seen no evidence for supposing that their relative position has ever sensibly changed. We must then suppose the dun-deposits to have been laid down about the close of the Sivâlik period, and probably more or less under local conditions produced by the contortion of the Sivâlik rocks. This last condition is more apparent in the case of the inner duns of the western region: it is only in the outer line of duns,—those of Dehra, Pinjore, and Una,—that any difficulty is encountered in separating the superficial deposits from the underlying disturbed strata. In the Nadaon dun, and in many

parts of the Kangra plateau, there are superficial clays and conglomerates lying thickly on an eroded surface of the gray, conglomeritic sandstone, which is there the youngest of the subjacent rocks. All these deposits must have been laid down before the excavation of the present great river gorges to anything like their actual depth, or else during the temporary obstruction of these gorges; in many cases indeed the latter alternative seems to be involved, for, the surface of deposition is but little different from that of the actual valley, and in some cases is nearly as low as the actual valley; as a cause for such interruptions I can only think of upheavals along the external zone of hills, the last effects produced during the period of disturbance. These considerations would seem to throw back the period of deposition of the dun-deposits.

Glacial debris of Dhaoladhar.

The most interesting of these deposits is that in which large erratic blocks occur so abundantly along the base of the Dhaoladhar. It first shows itself on the *east*, about Haurbaug, and is nowhere more strikingly seen than along the steep inner slopes of the duns east of Dhurmsala, where the huge blocks are thickly scattered over the surface. In viewing this deposit as the result of glacial action, I base my opinion chiefly upon the size of the blocks (I measured one twenty-five feet by eighteen, by ten), and upon some peculiarities of distribution. An eye more practised than mine in glacial phenomena might detect more direct evidence, but it certainly is not well-marked, and it is easy to account for the subsequent removal of all such traces of glacial action in such a position as this. The blocks occur at a present elevation so low as 3,000 feet above the sea-level, and they are found through fully a thousand feet in height. They are almost exclusively composed of the granitoid gneiss of the central mass of the Dhaoladhar, from which their area of distribution is separated by a lofty ridge of schists, through deep gorges in which they have evidently been conveyed, a huge block being occasionally found perched on the sides of these gorges, some hundred feet above the

present level of the stream; yet in such places I failed to observe any groovings or roundings of the rocky sides. The absence of evidence of this kind may, perhaps, be attributed to the rapidly disintegrating action of the heavy rains. I was many times puzzled to account for the positions in which these erratic blocks occur. They are frequently found on the slopes of the range, out of the way of any of these main gorges, and even up the little receding valleys of streams, which only drain the outer hills, and down which the blocks could not have come. Must we superadd the agency of floating ice? The total absence of erratic blocks in other positions is often equally puzzling. The position of this glacial deposit more to the west, in the confined and elevated longitudinal valleys between Sihunta and Choari impresses one more forcibly with the antiquity of its origin; it there lies in gaps and on ledges a full thousand feet over the deep drainage gullies close by.

Its possible explanation.

In attempting to account for the presence of glacial phenomena at so inconsiderable an elevation as 3,000 feet in a sub-tropical latitude, it were easy to appeal to that mysterious 'glacial period' which Mr. T. F. Jamieson has lately (Quar. Jour. Geol. Soc., London, Vol. XIX., p. 257,) suggested in explanation of some geological features of the Thibetan regions. I do not at all reject Mr. Jamieson's idea, but I hold that it is only to be called in when all other explanations are found untenable. I would suggest the following. Lofty as the Himalayas now are, I know of no physical hypothesis by which we are, *à priori*, forbidden to suppose them to have formerly been very much higher, not only by the amount removed by denudation, but as a mass; and for such a supposition I see some reasonable grounds. Towards the close of the Sivâlik period of deposition the Dhaoladhar may have been very much more lofty than now, and its valleys filled with glaciers: in sinking to its present level these would disappear, and the Sivâlik strata may have undergone their final foldings. I can find no explanation of the extensive folding of the Sub-Himalayan

rocks, except in the extensive sinking of the central mountain region; there is reason to think the action has been long continued and even intermittent.

Lakes.

Though, on the whole, these local surface-deposits of the duns seem to be more ancient than the Gangetic formation, we may find among them links of connection with modern deposits; there are still left some small lakes, now basins of deposition, which, I believe, owe their origin to the same causes as may have spread deposits over some of the inner duns. The lakes of Kundulu and of Morni are both situated just inside the boundary of the middle and upper Sub-Himalayan groups. The Kundulu lake is evidently only a deep mountain gorge, stopped up towards its lower extremity; and just here we find an axis of contortion. This lake has been much deeper than now; there is about half a mile of sloping delta at its upper extremity, which probably contains older beds than any now to be found at the surface of the Gangetic plains. It must not be forgotten that we have already proved the existence of the actual drainage lines or valleys, in the rocks of the older groups, prior to the Sivâlik period. There are at many places remnants of such detached lake-deposits; one of the most interesting I could mention is that among the slate rocks of the Lower Himalayas, about Haut, a few miles north-north-west of Subathu; it forms several square miles of level ground. The ravines of this area are cut through about 200 feet of clay and sub-angular gravel without reaching the rock. The sacred lake of Rurka, north-east of Nahun, lies in an abandoned portion of the bed of the Giri; this river having effected a new confluence with the Jalar, and adopted the course of the latter.

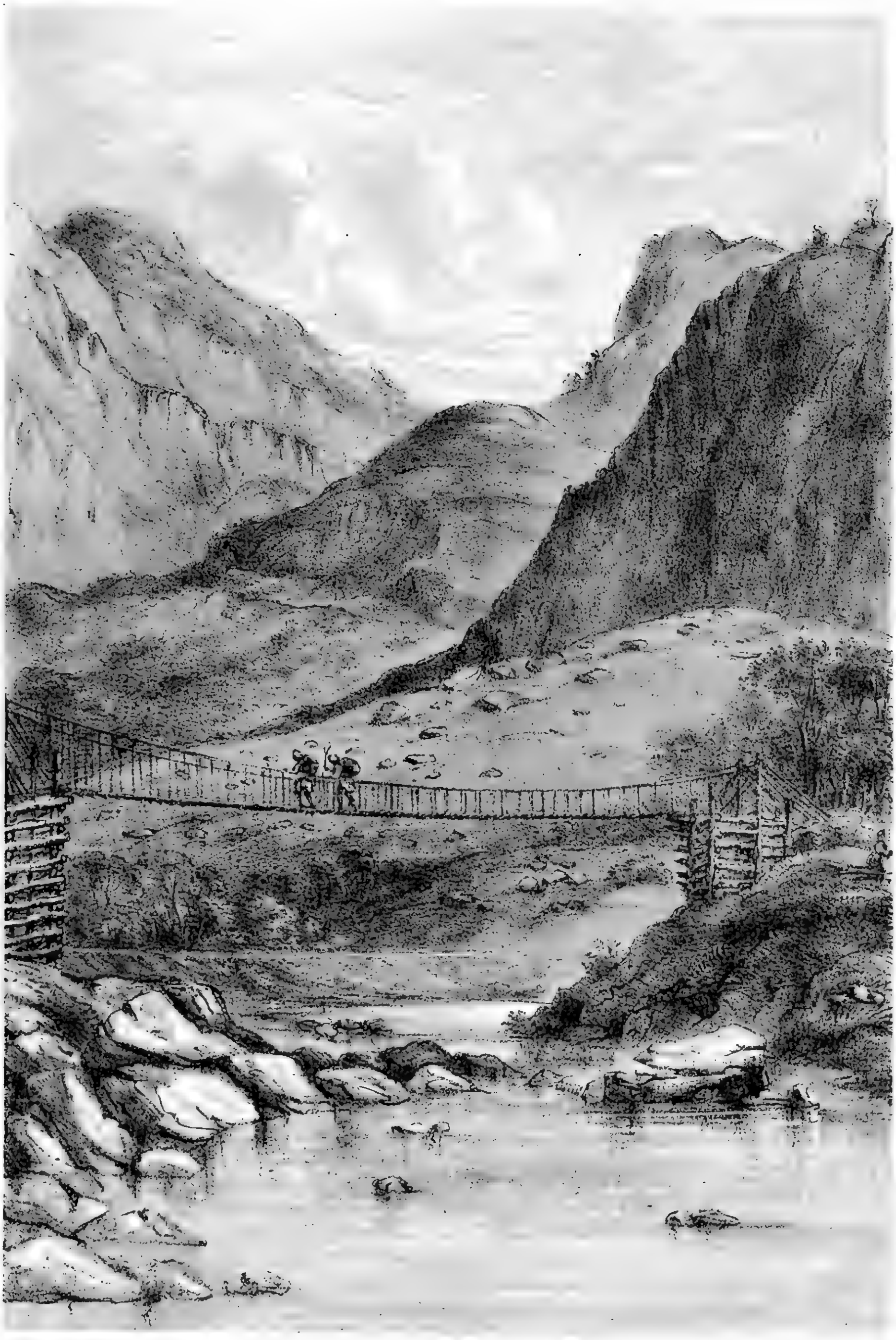
Rivers.

In connection with the subjects so briefly touched upon in the preceding paragraphs some mention should be made of rivers. It is only of late years that rivers have met with the attention they deserve as indicators of changes

at the earth's surface. One phase of their geological function has lately been ably treated in a paper, already mentioned, on the Ganges delta, by Mr. Ferguson; the author chiefly illustrates the action of rivers as agents of rock-formation, and, as contingent upon that process, he exhibits the mutability of rivers themselves. The antiquity of rivers, and their powers as agents of destruction might form the subject of an essay as instructive as Mr. Ferguson's, based upon a study of the Ganges and its great associates in the Himalayan mountains. It has hitherto been the fashion* to attribute the deep valleys, or rather gorges of the Himalayas, in a great measure to marine denudation, likening them to the deep fiords of the Norway coast. The simile reversed may be just as much to the point,—the Norway coast or any other such (I too speak without reference to details,) may be likened to a submerged mountain range. I feel assured that these valleys can all be more justly accounted for by river-action and atmospheric denudation generally, operating through the untold ages of the Sub-Himalayan epoch. Every reader of this memoir will be familiar with descriptions more graphic than I could give, and with sketches of the deep gorges of the Himalayas. I only add one view to the number already published. Plate III. exhibits a view of the gorge of the Tonse where crossed by the Simla and Masuri road, at the Tiuni bridge, a rude suspension bridge of native contrivance; at a considerable elevation over the stream glacial blocks are seen on the steep slopes.

The Ravee in its bend round the termination of the Dhaoladhar gives a good instance of a river course adapting itself to the conditions of rock-structure. At innumerable places on every river and stream we may find instances of the deliberate contravention of this apparently necessary law of natural selection as applied to river courses, and which breaches of law may safely lead us to infer very remote conditions of the surface,

* Dr. Thomson, "Western Himalaya and Tibet," p. 27; Dr. Hooker, "Himalayan Journals," Vol. I., p. 380; and R. Strachey, Quar. Jour. Geol. Soc., London, Vol. VII., p. 309.



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very different from what is now apparent. As examples of this I may mention the case of the Blini, where its course turns out of the band of soft nummulitic strata to cut a narrow gorge across the strike of the hard Infra-Krol rocks, to fall again, after two more bends, into the course of the same valley of soft rocks. The Sutlej at Bubhor gives another instance of the same kind. It cuts a narrow defile across the Naina Devi ridge, which is composed of comparatively hard rocks, in which no sign of crack or bend is traceable, whereas it might apparently, with much less trouble, have made its way round the point of the ridge, continuing throughout in the softer upper rocks.*

* For those who wish to see facts of this kind discussed in some detail, I may refer to an excellent paper by Mr. Jukes "on the mode of formation of some of the river valleys in the south of Ireland" (Quar. Jour. Geol. Soc., London, Vol. XVIII., p. 378).

CHAPTER VI.—*General discussion of the structure of the hill ranges.*

Colonel Strachey's views on the structure and history of the Himalayas.

THE Himalayas, from several points of view, have formed the subject of many scientific speculations. The only general discussion of them, however, based upon *geological* observations, with which I am acquainted, is that by Colonel R. Strachey, published in two papers in the Quar. Jour. Geol. Soc., Lond., Vols. VII. and X., 1851 and 1854. It is deeply to be regretted that this accomplished observer has not leisure or opportunity fully to work out the abundant materials he has accumulated; he could, no doubt, give a much more complete account than is contained in his brief papers to which alone I can refer. Colonel Strachey boldly attempts a general sketch of the physical history of the Himalayas, fully aware, no doubt, of how precarious and speculative such an attempt must be upon data so incommensurable with the magnitude of the problem. In this case, however, it is somewhat justifiable on the grounds that except this attempt were made, the large mass of facts, which was growing so unwieldy with the accumulated observations of many years, would remain as so much dry detail, unprofitable to the interests of general physical science. Premising the well-established fact that great areas of the earth's crust have undergone actual upheaval, Colonel Strachey states his conviction that the Himalayan mountain mass was so upheaved. He then calls attention to a series of facts, from which he draws conclusions as to the extent, amount, direction, and duration of that upheaval. Most of the observations upon which his views are based were made outside the region described in the foregoing Chapters; it will be necessary briefly to notice them. The region to which Colonel Strachey's observations more particularly refer is that of Naini Tal and Niti, in Kumaon. He describes the double fringing zone of younger

rocks, which he supposes to be separated from those inside them by a series of great faults, and then passes to the description of the argillaceous schists and limestones associated with trappean rocks, which form a continuous belt along the outer limits of the Lower Himalaya. His description next embraces a broad tract of mica-schists, in which occurs a run of granite, showing intrusive action along the lines of its contact with the schists. In the northern part of this band of sub-metamorphic rocks, he notices three changes of dip with dislocation of the strata, and in one case trappean intrusion ; in this part of the zone also limestone is common. The zone of partial metamorphism, his description goes on to say, is succeeded on the north by the band of thoroughly crystalline schists, in which occurs the line of peaks. Along this line there are invariably seen, for a breadth of several miles, veins of granite in great abundance, penetrating the schists, often cutting through them, but most frequently following the bedding, in which the same general dip, as elsewhere, to the north-north-east, is pretty constantly observed. In some places, he states, the granite forms whole mountains. In this region also beds of limestone are of frequent occurrence, always highly crystalline. Along the north side of the line of peaks the schists are overlaid by slaty rocks, about 9,000 feet thick, the bottom beds of these are coarsely conglomeritic, and are also to some extent penetrated by granite veins, but on the whole the contrast with the gneissose rocks is well marked. The slates are followed, he says, in regular succession by about 6,000 feet of palæozoic rocks, consisting of limestones, slates, and grits, capped by quartzites, which form the peaks of a second line of ridges. Still further to the north we are brought to the lower and middle secondary rocks, principally limestones, 5 or 6,000 feet in thickness, showing parallelism of dip and strike with the rest of the section. In the upper part of this section the frequent occurrence of eruptive greenstones is noticed, and that the rocks begin to be covered by the deep superficial deposits which form the great plateaux of Thibet

These deposits are very thick in some places, nearly 3,000 feet, and cover an immense area, being probably the same as have been described far to the west and to the east of this region. It is principally on this circumstance of uniformity and extent that Colonel Strachey bases his opinion, that the deposits are of marine origin. No marine remains have been found in them, but, on the contrary, they contain bones of large mammalia of extinct varieties.

Besides the more special observations that have just been enumerated, there are general features upon which Colonel Strachey's hypothesis more immediately rests. The area to which he extends his generalizations reaches from the plains of India to those of Central Asia, and longitudinally, in a north-west and south-east direction to the supposed limits of the chain. On the transverse outline of this mass the Himalaya and the Kuenlun occupy the line of demarcation of the southern and northern slopes, and the table land of Thibet occupies the summit of the protuberance,—an arrangement with which is connected the great central longitudinal, and the deep lateral, systems of drainage. Throughout the whole area we may notice the mutual parallelism of the great ridges and of the outer limits of the area, of the strike of the strata, of the lines of igneous action, and of the distribution of the rock groups. Attention is further drawn to the fact of the constancy maintained for great distances longitudinally both in geological structure and in the elevation of the mountains.

At this point of the argument the author's opinion regarding the marine origin of the plains of Thibet leads him into what I cannot but consider inextricable difficulties. The elevation of the Himalayan mass, as we know it, and through at least 17,000 feet, is thus brought within a very late period of the earth's history; it is this last great movement of Himalayan elevation that forms the principal subject of Colonel Strachey's second paper. It is not the question of time, against which we can raise no *à priori* objection, which

makes the problem a difficult one; the difficulties are principally physical and mechanical, for, these deposits, be it remembered, rest undisturbed in the great valleys of Thibet. Nor again can we assign limits to the powers of continental elevation,—elevation without rupture or disturbance. But this is not the agency to which Colonel Strachey appeals; his theory (which is that of Mr. Hopkins) is essentially one of local (as opposed to cosmical), special upheaval. This being the problem, it is evident that a great part, we might almost say, *all* the positive part, of the evidence already stated, becomes irrelevant, namely, the parallelism and constancy of the granitic axis, of the observed dislocations, and of the attendant trappean intrusions, of the strike of the strata, and of the groups of strata, these being demonstrably anterior to the upheaval under discussion only prove the coincidence in direction of distinct acts of upheaval and leave the supposed case entirely dependent upon its own independent evidence. The author was perhaps aware of this irrelevancy, but he does not state it with quite sufficient distinctness, nor does he keep his independent evidence sufficiently separated from that of the other phenomena. He gives his opinion that the granitic axis is of pre-Silurian origin, and that none of the igneous rocks were "specially related to the last great movement." Hence, having nothing tangible to point to, he infers that the agent of elevation was probably a development of elastic vapours at a great depth. In this, as in every other feature, Colonel Strachey assimilates the Himalayan elevation to the theory of Mr. Hopkins, in which the form of the area affected and the relations of the fissures produced by upheaval were the main elements of discussion.

Thus, finally, Colonel Strachey has to rest his theory upon a few "observed facts" of very doubtful validity. These are:

1*st*. *The existence of longitudinal and transverse fissures.*—But any longitudinal fissures of which observations have been published, even by the author himself, can be referred with very great probability

to periods anterior to the movement in question. And, as far as I have been able to examine any of the great river gorges,—of the Ganges, the Jumma, the Tonse, the Sutlej, the Beas, or the Ravee,—there is little or no evidence for referring them to transverse fissures, and certainly there is none since the beginning of the Sub-Himalayan period.

2nd. *The more open character and greater importance of the longitudinal fissures in the centre of the area, as evinced by the direction of rivers on the Thibetan table-land.*—The very existence of these longitudinal fissures in Thibet rests upon no evidence whatever that I have ever heard of beyond the fact of there being great longitudinal river valleys: and the inference from such evidence is by no means necessary. It is inconceivable to me what could be the nature of fissures so great as those supposed, yet which could be produced without disturbing *in any degree* the great valley deposits, to explain the elevation of which these imaginary fissures are brought in as evidence. But this is not the only case in which this difficulty is introduced. The author explains the separation of a patch of superficial deposits, observed south of the Niti pass, from the main mass of those deposits, in Thibet, by the dislocations which accompanied the upheaval.

3rd. *The existence of an important line of fissure along the outer margin of the Himalayan slope.*—The conditions of the rocks along the south base of the Himalaya might easily be interpreted to suit this theory. But the most considerable movements of upheaval (that of the Subathu group,) in this zone can be shown to be anterior to the time of the supposed great elevation; I have also shown, that there is no great uninterrupted line of fissure. However, by the admissible assumption, that the Thibetan tertiaries are of Sivâlik age, or at least anterior to the disturbance of the Sivâlik strata, and by setting aside some plain probabilities, the evidence of this disturbance might be interpreted to fix the limits and amount of this last Himalayan elevation.

4th. *The occurrence of two lines of least rupture, parallel to the margin of the area, and intermediate between it and the axis.*—It is only regarding the southernmost of these, the area, I have spoken of as the Lower Himalaya, that we have any information whatever. The contortions and dislocations of the strata of this area, being demonstrably connected with the more ancient phenomena of disturbance, it can, of course, be assumed that none of them are connected with the elevation in question.*

These are the facts, or supposed facts, upon which Colonel Strachey bases his account of Himalayan upheaval. But the *primâ facie* evidence against the supposition upon which the necessity for such an hypothesis of upheaval rests, seems to me very strong. As far as one can judge from written descriptions, (and the opinion has been advanced by some observers,) those Thibetan tertiaries are deposits of great valley-lakes. If the presence of large mammalian remains (of the rhinoceros and his associates) should be thought an objection to the supposition lately made by Mr. Jamieson, (Quar. Jour. Geol. Soc., London, Vol. XIX., 1863,) that these lakes were caused by the damming up of the valleys by glaciers, it may be possible to find a suitable and admissible explanation in the moderate dislocations and changes of level, for which independent evidence can be found. The explanation I have given of the disturbance of the Sivâlik rocks involves conditions precisely such as would produce great lakes in the central mountain region.

Before indicating the few conclusions I am able to arrive at regarding the structure of the Himalaya, I will here just mention some isolated observations of much interest. We have already (page 88 and note, page 92) discussed some surmises as to the existence of nummulitic strata among the rocks of the Himalayan series, along its southern limits, in what I have

Nummulitic rocks in the higher Himalaya.

* Colonel Strachey gives a fifth article of evidence, which however does not appear to bear on the question of upheaval now under discussion.

described as the Krol group. Other cases occur in the inner regions.

Vigne.

Vigne, in his "Travels in Kashmir," 1842, Vol. I., page 276, mentions the occurrence, on the eastern side of Manasu Bul lake, in the Kashmir valley, of a limestone, full of nummulites. In a letter lately received from Mr. Drew, who is engaged in a geological investigation of these interesting regions, he tells me that he could not find the nummulites or any other fossil in or about the locality; he says, "I fully believe Vigne was misled by an appearance, certainly very like nummulites, on the weathered surface of the limestone, where it is made crystalline by being near trap." There is another statement of the occurrence of these nummulitic rocks, which

Thomson.

I cannot presume to call in question. Dr. Thomson, in his "Western Himalaya and Tibet," 1852, p. 381, describing the Singhi La pass,—a locality a short way south of the Indus, in the central mountains of Thibet, in about the same longitude as Mundi, and the same latitude as Srinagar in Kashmir, at an elevation of over 16,000 feet,—says :—"Quartz rock, slate, and limestone alternated during the ascent; and near the summit of the pass the limestone evidently contained organic remains, perhaps coralline, though their traces were not sufficiently distinct to enable me to decide the point." This, however, has been done : M. d'Archiac describes these fossils (Groupe Nummulitique de l'Inde, p. 176) as *Alveolina Melo*, and, doubtfully, *Nummulites Raymondi*. The conjecture again presents itself that these rocks may be the same as the Krol group, described in Chapter II.

Hooker.

In Vol. II., p. 156 of his "Himalayan Journals," Dr. Hooker records a geological observation made at about the most northerly limit of his travels, within the frontier of Thibet, on the northern flanks of Kinchinjow; at this place conglomerates, slates, and earthy red clays overlie the gneiss, all having a north-east dip; further on a dark limestone occurs, "full of encrinitic

fossils, and probably nummulites." Independently of the doubtful fossils, this observation shows the wonderful constancy of the stratigraphical arrangement. At the southern limit of this Himalayan area, explored by Dr. Hooker, this distinguished naturalist made a discovery of great interest. In Vol. I., p. 403, he describes having found in the Baisarbatti, below Punkabaree, carbonaceous shales containing *Trizygia* and *Vertebraria*,—fossils characteristic of the Indian coal-bearing series. These shales dip at 70° to the north, and are overlaid abnormally by the metamorphic clay slate of the mountains. Thus this rock bears just the same stratigraphical relations to the older rocks of the Himalayas as do the Sub-Himalayan strata,—a fact which complicates our speculations not a little, when we reflect that, as far as we can at present conjecture, these plant-rocks belong to some period, possibly a low one, of the secondary epoch. From some other observations, recorded by Dr. Hooker in the same locality, it would seem that the Sivâlik series is also represented in the same section.

Generalizations on general structure and history from the observations I have recorded.

The uniformity of the characters of disturbance stamped upon the whole series of Himalayan rocks is certainly very striking. With the exception of instances in which a local cause can be assigned, there is scarcely an exception to the prevalence of a north-west-by-west direction in the features of disturbance, gradually changing to an east and west direction towards the eastern end of the chain. When we first attempt to generalize from the broad facts of the case, this appearance of uniformity almost grows into a conviction of unity, which can only be dispelled or modified by a closer examination of details. The area shown on our map is a very partial one; the first inspection of it indeed suggests diversity rather than uniformity. We have here, I believe, the beginning of the end; many

of the features appearing as patches on the map are but the termination of those which we know to be more or less continuously represented for several hundred miles to the eastward. In this respect the position is favourable; we can here add the coincidence of the simultaneous partial extinction of the several features to the coincidence of their continuity elsewhere. The agreement seems wonderfully complete. In the Dhaoladhar at Dalhousie we seem to have the termination of the great line of the Eastern Himalaya, at least in its character of an axis of crystalline intrusive rocks. The minor characters are in keeping with this supposition: what we have seen to the eastward described as a broad band of thorough granite, distinctly intruded, is here represented by granitoid gneiss showing quasi-intrusive characters. At what we might consider a due distance from the end of the main line of elevation the whole area of the Lower Himalaya disappears, and the stratigraphical conditions show that this is connected with the structure: the strike of the rocks bends round with the boundary, the cross-section of which throughout the bend is quite the same as elsewhere. Throughout all these changes each zone of rocks is represented. The peculiarities we have noticed on the Chor correspond with those of the Dhaoladhar; it is a gneissose, quasi-intrusive mass, and may here represent the more truly granitic rock of the middle zone in the sections further to the east. Even in the Sub-Himalayan series the same facts are observed; the Subathu group becomes covered up west of the Sutlej, the middle group disappears in the same manner, and we have seen that the successive ridges of the upper group are cut off *en echelon* in the region of the Beas. It will be remembered that in Chap. III. (p. 19) it was stated that in Huzara, west of the Jhelum, a different system of disturbance prevails, running nearly at right angles to that of the Himalaya, and deeply inserted into the prolongation of the Himalayan area west of Kashmir.

The region of our map peculiarly fitted to warrant general conclusions on the disturbance of the whole mountain mass.

The *prima facie* interpretation of all this superficial symmetry would be that it had been produced by one great act of upheaval, subsequent to the formation of all these rocks, having its axes of maximum effect,—one at, or north of the line of peaks, and the other well to the west of the Ganges. The difficulty, as it now presents itself, is to reconcile so much symmetry with the great difference, both in time and in mode of production, which can be almost demonstrably established. The problem is brought within small compass in the section of the Dhaoladhar (p. 63). The structural features of that section would accord well with the supposition that the granitoid mass forming the ridge had been introduced by faulted intrusion subsequent to the formation of the Sub-Himalayan strata. It has, however, been shown that when these rocks were formed the ridge existed pretty much as it does now, and that the boundary between them and the older rocks is to a great extent an original one, their relative positions having never much altered. In the case of the upper Sub-Himalayan group, which is often much more disturbed than it is represented in this particular section, it was shown to be contemporary with the existing river gorges of the mountains. It is in the region of the Lower Himalaya that this distinction can be best studied. We there find a zone of maximum contortion along the line of contact of the Sub-Himalayan with the Himalayan rocks, and separated from the great range of the Eastern Himalaya by a wide area of comparatively little contortion and of somewhat different character.

Is the theory of the features of disturbance being due to one great act of upheaval, after the formation of all the rocks, tenable?

Objection to it.

These remarks seem to me to lead to the conclusion that the features of disturbance in these youngest rocks have no direct connection with *the formation of the mountains.* But connection there most decidedly is. I believe the disturbance of these rocks to be entirely a *reflex* effect. As the composition of the Sivâlik strata and

Features of disturbance in younger rocks probably not connected with the formation of the mountains, but indications of their subsidence.

their enormous accumulation give evidence of the vast denudation to which the older Himalayan rocks have been subjected, so the disturbance of these strata gives more positive evidence of a period of *decadence* of the Himalaya. I can see no explanation of these contortions but in the thrust from the mountain mass consequent on the sinking of that mass. Should this conjecture be well founded, we have an example in the straight lines of flexure and of fracture of the Sub-Himalayan rocks between the Sutlej and the Beas of how accurately such testimony can be in accordance with the primary features of a mountain range and those which appear to be necessarily connected with its growth. It would be in agreement with the same opinion to suppose some or all of the general upheaval, which this outer zone has undergone (independent of that due to contortion), to be an effect of the same cause—the tendency to establish an equilibrium of pressure.

Difficulty of drawing a line between the rocks affected by the two systems of disturbance respectively.

If once these views have been admitted, it is manifestly difficult to draw the line between the secondary and the primary contortions. All contortions are necessarily the result of *lateral* force. In the case we have just described, the force is altogether external, and the contortions might be called secondary. When the force is exerted within the mass acted on, as in a mass compressed by its own gravitating tendency, the resulting contortions might be called primary; they would perhaps be more regular than in the other case. The flexures in the old Himalayan rocks may be of this kind. From this point of view there are many reasons for associating the calcareo-shaly band, which I have described as the Krol-group, with the younger rather than with the older strata. Its contact with the latter is almost always abrupt, and, in many cases, as that described in the valley of the Sutlej, the junction is more easily explained by supposing it to be, as in the case of the sub-Himalayan rocks, an original boundary only

To which system should the Krol-group of rocks belong.

modified by disturbing action rather than altogether due to this latter cause. In their position as the fringing band of the higher mountains, these limestones and shaly slates exhibit the sharply crushed type of contortion rather than the large waving of the older rocks. Various arguments, as already detailed, have referred these Krol rocks to two very different periods, the older palæozoic and the older nummulitic. The general argument here stated can scarcely be assumed in favour of either view, though we are predisposed to give it in favour of the latter ; its only direct and independent bearing is upon the question of the mountain structure. The age of this group, and the identification of it at different points of the chain, seem to me the most pressing questions in Himalayan geology.

Older system of disturbance.

We next come to consider the state of the older rocks. In them we find the same grand rule obtains as in the newest Sivâlik strata, namely, a prevailing north-easterly dip,—folded or normal flexures directed from the north-east. In accordance with the strictly elevatory theory he adopted, Colonel Strachey (Quar. Jour. Geol. Soc., London, Vol. X., p. 252) explains the feature in both cases alike, by a repetition of the same phenomenon of *upheaval.*

Colonel Strachey's views on the prevailing north-east dip.

The most difficult part of the question is assumed, namely, the initial stage of the phenomenon, which seems to me could never result, indeed would be the very contrary of what one must expect, from the conditions of Mr. Hopkins' theory. The appropriate inclination, however, having been once imparted to the great blocks of the earth's crust between the fissures, the recurrence and constant increase of the inclination is accounted for by the fact that the resultant of upward pressure would not pass through the centre of gravity of the inclined block ; the Sivâlik strata having been deposited upon the denuded edge of these tilted blocks, acquired the dip due to the subsequent tendency to revolve when the block is pressed from below.

Objections.

The detailed features we have observed in the Sub-Himalayan rocks

are incompatible with such an explanation. They are connected with flexure, not sheer faulting, and in the best established instances of faults the *down-throw* is oftenest on the *north-east* side. I attribute all to the pressure of the mountain-mass.

Conclusions on the disturbance of the older rocks.

In the older rocks we must, I think, look *nearer home* for the immediate cause of this prevalent mode of disturbance, and there seem to be inevitable reasons for connecting it with the elevation of the rocks. We thus, through what I will venture to call the impossibility of accounting for this dip as the result of any *independent* direct source of elevatory action, such as the development of elastic vapours, are able to eliminate such a cause from our speculations regarding the elevation of the Himalaya. The Chor and the Dhaoladhar, especially if we can look upon them as the representatives of the true granitic intrusions of the eastern regions, give us important suggestions: they connect the mode of contortion with the introduction of the hypogene* intrusive rocks,—a definite direction of lateral force immediately associated with a product of a known source of mechanical force. If this coincidence be not fortuitous, if both phenomena be not the result of a general cause, we are led to infer, with Colonel Strachey, but on different grounds, that the line of peaks, which is the line of granitic intrusion, is to the south of the centre of energy; but the same facts would lead us to conjecture, differently from the same author, that the granitic intrusion is connected with the principal act of formation of the mountain mass, by which the palæozoic and secondary rocks of Thibetan regions were brought into their present positions. This question of the granitic axis is a very interesting one; Colonel Strachey, although he mentions the occurrence of granite veins in the bottom beds of the Trans-Himalayan unmetamorphic rocks, shows good reasons for supposing the

* I use the word *hypogene* simply as conveying the opinion, I believe universally accepted, that granite, as such, cannot be a superficially-formed rock.

pre-existence here of granitoid rocks. This, however, does not interfere with a later intrusion of granite. The altogether lateral position of this ridge in the mountain system precludes the idea of its being in any sense a central axis of Himalayan elevation; yet its structure seems to require its close connection with that system, and to preclude the idea of its being a partially independent ridge of early origin, such as the eastern ridge of the Andes is represented to be.

On the whole, the interpretation that seems to accord best with the little information we possess regarding the central mountain region is an adaptation of the Babbage and Herschell theory, assimilating the case to that of the Appalachians as explained by Mr. Hall; it will serve at least to fix our ideas. A great area of subsidence to the north of the crystalline axis, connected with, if not caused by, great deposition, and entailing compression by which flexures of contortion were produced from the northwards: a line of weakness, perhaps induced by denudation, along the present granitic axis, which would thus have become a line of relative upheaval accompanied by intrusion. The granitic character of this intrusion may be largely due to the nature of the rocks passed through, the same material may have turned into trappean rocks among the highly basic strata to the north. The subsequent general upheaval of the area would, under the same theory, be explained by the slow thorough heating of the newly made crust and of the mass beneath it.

It is, however, difficult to reconcile the mode of explanation I have just applied to the elevation and contortion of the older rocks with the view I have taken of the similar phenomena in the Sub-Himalayan regions. Elevation by heating is a mere swelling (not involving an increased accumulation of matter) and the only provision the theory makes for its reduction is loss of volume by loss of temperature consequent upon denudation. Subsidence of this kind could hardly produce the lateral pressure, of the occurrence of which, subsequent to the

formation of the mountain chain, we have seen such good evidence in the Sub-Himalayan rocks. That pressure seems to involve the removal of some positive sustaining force, such as M. de Beaumont's *bossellement,* or something still more vague and unknown.

I will conclude by briefly enumerating the principal conclusions to which we have been led by the study of the area, to the description of which this memoir is specially devoted.

The Himalayan mountain area was defined before the deposition of the Subathu nummulitic rocks.

Throughout all the succeeding Sub-Himalayan period, the same limit of deposition has obtained.

During the deposition of the upper group of this Sub-Himalayan period, the very mountain streams were the same as now exist.

The Krol-group—the youngest of the older rocks—though greatly denuded, had undergone little or no contortion along the outer zone of the mountain area, prior to the formation of the Subathu nummulitic rocks.

The special elevation of the Subathu group indicates that an upheaval, coinciding in direction with that of the Himalayan area, took place (east of the Sutlej,) before the deposition of the next succeeding group.

That a phenomenon of a similar kind determined the separation of the succeeding groups.

That the contortion and fracture of the Sub-Himalayan rocks is a reflex effect produced by the subsidence of the mountain-mass, the upheavals of the same zone being probably an effect of the same cause.

CHAPTER VII.—*Economic Geology.*

Supposed mineral wealth.

So much has been said, and is believed, about the boundless mineral resources of the Himalayas, that I feel it is at great disadvantage that I am obliged to take up the opposite side of the argument. It would, I believe, be difficult to find elsewhere an equal area of mountain country so barren of mineral wealth. For those who are sceptical about geological opinions on such matters, there is an argument which seems to me of much weight; it is, that the natives know nothing of these treasures. There are not very many useful materials with which they are not more or less acquainted. In their miserable way they can work ores at a profit which could never remunerate the European manufacturer. Those whose trade and caste it is to deal in minerals are very expert in recognizing and detecting signs of mineral deposit. I have seen a native set to work to grub for ore in a place where no one, who had not made a special study of the district, would have suspected its existence; yet the discoveries they have made in these mountains are very far from promising. There is, however, a consideration which may reconcile us in some measure to this scarcity. These mountains are so difficult of access, that, except their mineral products were of the most valuable quality and occurred in the richest abundance, they would still remain profitless. The case of iron illustrates this statement: at many places in the Lower Himalayas iron ore of the richest quality occurs, but is now, and probably must long remain, useless to the country at large on account of the difficulty of bringing it to market.

Building Stones.—Those stations, as Dugshai, Kasaoli, Subathu, Dhurmsala, which are built upon the lower groups of the Sub-Himalayan series, have an unfailing supply of good building material in the

massive sandstone rocks. Among the older rocks there is no stone fit for anything but that for which rough rubble may be used. There are several examples of native architecture along the border of the plains, for which an excellent building stone was obtained from rocks of the Sivâlik group, but it must have been found in detached blocks and discontinuous bands, the mass of the rock being quite unfit for the purpose. Stone fit for ornamental or monumental purposes might be found among the thick-bedded, hard limestones of the Krol group.

Slates.—The absence of building stone among the rocks of the Himalayan series is in some places atoned for by the existence of a good roofing material. Mention has already been made of this substance at p. 72, in connection with the subject of cleavage. The variety of slate procured along the flanks of the Dhaoladhar, and used at Dalhousie and Dhurmsala, has proved of first rate quality for roofing purposes. Its fissility is all that need be desired ; it dresses easily, and can be procured of ample size. It is a nearly pure siliceous rock, of pale gray colour, and is not so fine in its minute texture as ordinary slate, and is therefore not applicable to some purposes for which the latter is used. The slate so extensively used at Simla is in every way inferior to that of the Dhaoladhar ; it is distinctly a lamination-slate. A material as good as this could, I imagine, be found among the Infra Blini strata almost at any point, unless of course where crushing action had been excessive.

Lime and Cement Stones.—Here, as in all parts of India, the stone most in favour with the natives for burning into lime is porous tufa. The climatal conditions are peculiarly favourable to its production. It is to be found everywhere along the flanks of the limestone ridges, and in many places, where its existence is not so easily accounted for, on ledges, and in little basins of the Sivâlik rocks. In many cases these basins are evidently small dried-up lakes; they may all have such an origin. Lime is in many places obtained by burning boulders

picked out of the beds of torrents; the quality of lime thus obtained is necessarily very uncertain. There are some fine-grained, earthy limestones of the lower Krol band, which would be well worth experimenting upon to obtain a cement stone of certain quality. The want of such a material is greatly felt in the extensive irrigation works all over upper India.

Gypsum.—Gypsum is found in moderate quantities at many parts of our district. It occurs in lumps through the ferruginous clays of the Subathu group. At Sahansadhara, below Masuri, it occurs in small irregular veins through limestone, in the neighbourhood of the sulphurous springs. From both these sources a small supply is brought to market, the demand being very limited.

Salt.—At page 60 I have given an account of the salt rock of Mundi, in the strata of the Krol group. I there stated probable reasons for its local occurrence in that group. The very profitable nature of this mineral, as an article of commerce, has naturally excited the attention of speculators, both scientific and practical. Shafts have been sunk in the Nahun sandstone below Masuri, about the Noon river, and small works erected for the preparation of the salt. This speculation had a two-fold foundation,—a small amount of fact, and a great deal of supposition. The former consists in the occurrence of a saline spring. I never could get exact information as to the position of this spring, its yield of water, or the precise composition of its saline produce; the locality indicated to me by the natives is at the outer edge of the Nahun band, at the foot of the slopes of the lignite sandstone. It seemed to me that briny water in such a locality might possibly be derived from the concentrated exudations of the rock above, which here, as elsewhere, effloresces copiously under the influence of the sun and rain. Practical men, of course, were influenced by the assumption that the rock was the same as that in which salt is found to the north-west. The fact of there being a

spring, or at least saline water, must remain for what it is worth; but it can be asserted with much certainty, that salt in this position can have no connection with that at Mundi, or in the Salt-Range, nor yet with the saliferous system of England. The name given to the river by the natives, Noon or Loon, the word in the hill vernacular for salt, has I am satisfied had much to say to confirming a belief in the presence of the mineral.

Iron.—At very many places throughout the hills, iron ore occurs in sufficient quantity to be worked by natives for local demand. But at several places excellent ore occurs in profusion; I may mention the vicinity of Ramgur in Kumaon, Shele east of Simla, and Kohad in Chota Bhagul. The ores are magnetic, and micaceous iron; they appeared to me to be metamorphic deposits, and are probably more or less strictly representative of each other throughout the middle zone of the Lower Himalaya. The ores which attract the most notice as likely to give a return to manufacturing enterprise on a large scale, are those occurring at or near the base of the mountains. The only well-known deposit of this kind is at the foot of the Naini Tal hills, in the clays at the base of the lignite sandstone. The ore is an irregularly segregated red hæmatite, with in some places a considerable proportion of brown hæmatite. The whole stratum, ten to twenty feet thick, is sometimes workable; elsewhere it is no more than a ferruginous clay. There have been extensive preparations made to work this ore at Kalidoongi and Dechourie; the only apparent obstacle to complete success is want of communications,—means of commanding a market. The question has been very fully discussed in several reports to the Government of India. Whether this ore can be found at other places along the same line of hills is a matter of much interest. Very strong statements have been made in favour of its occurrence. There is no doubt that it is *represented* uninterruptedly along this zone as far as the true Nahun band extends. I have mentioned

the existence of highly ferruginous clay at the very base of the hills, north of the Kyarda dun, opposite Kolur, and more or less ferruginous clays are to be found at many intermediate points, but I have not seen a single locality where I could, with any confidence, affirm the presence a workable deposit; however, I grant the probability that such may be found. The case is a very simple one; there is no concealment about it; the ore is very much harder than any of the rocks with which it is associated, and must be freely exposed at the surface; at Dechourie and Kalidoongi immense blocks of it reveal the outcrop to every passer by.

Copper.—Copper is prepared to some extent in the provinces of Kumaon and Gurhwal. Mr. Henwood, whose opinion should stand very high reported unfavourably on the deposits of ore, from the point of view of the European miner.

Lead.—On the banks of the Tonse, about twenty-five miles above Kalsi, there is a small district, partly in Sirmoor and partly in Jaonsar, from which lead has been procured to a considerable extent. The rocks in which it occurs are the limestones and slates of the Krol and Infra-Krol groups, greatly disturbed. There was but one mine open at the time of my visit. At the only place where the work was being carried on, the lode was very well-defined, underlying at 70° to east-north-east, about two feet wide. The galena occurred in a thick steady string, principally next the under-wall. Associated with the galena, though keeping rather distinct from it, is a string of mixed ore, principally zinc-blende, with some galena, iron pyrites, and quartz. The galena contains only a small per-centage of silver. At the gap between Geruani and Guma, there are old mines in the same rocks, and which, I was told, had been lead mines.

Gold.—There are gold-washings carried on yearly in the beds of the Himalayan rivers, and most extensively, even in streams which only drain the Sub-Himalayan rocks. The fact is rather interesting; since in these streams the gold must have a doubly derivative origin.

Graphite.—Graphite has been procured from several places in the Lower Himalaya. Colonel Drummond, who has done so much to develop the mineral resources of the province of Kumaon, obtained some very fair samples of graphite in the neighbourhood of Almorah. The circumstances of its occurrence there are interesting, and very analogous to what I have described in the carbonaceous, slaty shales of the Infra-Krol band. There seemed to be a band of graphitic schists, regularly associated with the other metamorphic strata of the district, and promising to be of great service in tracing out the details of the stratigraphy. The best lumps of graphite have been found where this schist has been crushed along a fault or line of strain, and the graphitic matter has somehow become concentrated in lumps of various size.

Coal.—The question of the discovery of coal in these hills has so often attracted local public attention, that it may be well to make a few remarks on the subject. I would not by any means deter any explorer from keeping his attention upon so important an object, but it is right to make known the results of experience. There are two groups of rocks in which supposed coal discoveries have been repeatedly made, in the sandstone rocks of the lower hills, and in the black, shaly rocks occurring beneath the limestones of the fringing zone of the higher hills. I have seen a great deal of both these rocks, and I think that the prospect of a useful deposit of coal being found in either is very unpromising. The nests and strings of lignite that occur, sometimes close together, in the sandstones, are manifestly the remains of isolated trunks or roots of trees, which were rolled or floated into these positions and became buried in the sand. There is, of course, the chance of a great local accumulation of such matter; but such has not been the mode of origin of useful coal-seams. The carbonaceous shales of the Infra-Krol band offer at first sight a more promising field of research (vide p. 29). Without an extensive exploration of these shales, I should

not have relinquished all probability of success. In the many scores of sections I have examined in these beds, within the region from the Ravee to Naini Tal, I have never found a single grain of true coaly matter. The case seems to be somewhat different far to the north-west, if my conjecture be correct that the shales of Dundelee are the representatives of the Infra-Krol beds. At that place there *are* strings of anthracite-coal in the slaty shales, but the condition of the rocks is very discouraging to a prosecution of the enquiry.

Water.—The question of water-supply is one of great importance at all the hill stations. The expense of carrying water up several hundred feet of steep hill, on the backs of men or of mules, for the supply of a large military depôt, is enormous. The stations are always perched on the crests of a ridge, and, of course, all the springs are at a greater or less depth below, according to the nature of the stratigraphy. Some years ago, in cutting a tunnel for the new road to Simla through a ridge near Dugshai, the continuation of that on which Subathu is built, it was found that after piercing the hill to the distance of a few yards, water issued abundantly from the cutting, and continued to do so. The intelligent and enterprising officer in charge of the works took up the idea that the same result might be attained anywhere, and at once drew up a scheme for applying his discovery to Simla and Kasaoli. An experiment was sanctioned for the latter place, and the work was carried on vigorously; several hundred feet of tunnel were cut, but without drawing the expected supply of water. The scheme was, of course, abandoned. A comparison of the two sections at once explains the different results. It would be difficult to imagine conditions more favourable than those in the ridge of the road tunnel near Dugshai. This ridge is formed by the extension, along the strike of the rocks, of the southern half of the Boj mountain, as represented in Fig. 3, p. 24. The valley on the north of the ridge is formed along the anticlinal bend of the Infra-Krol group ($c.^2$); thus on both sides of the ridge the strata dip inwards,

and the water necessarily soaks in the same direction ; the crushed rocks along the junction of the formations, running nearly along the centre of the ridge, act as a conduit and receptacle for this water. The case of the Kasaoli ridge may be seen in Fig. 2, p. 18; the unbroken strata of sandstone dip at a high angle in one direction; the side of the ridge along which these beds crop out is almost a sheer cliff. Failure in such a place might have been anticipated. It was shown, however, that the conditions of the rocks at Simla are more favourable. Jako is a broad massive hill, rising more than 500 feet over the point where the water is most needed; it is well wooded and deeply covered with soil; the rocks are soft, decomposing schists, and are a good deal crushed and waved. The authorities were persuaded to give the experiment a trial here, and they have been rewarded with success. A tunnel was made to the depth of 800 feet, when a sufficient supply was obtained. It has now stood the test of two dry seasons. Under proper direction, the system might be extended with more or less of advantage to most of the hill stations. I know none of them so unfavourably circumstanced as Kasaoli.

Pure water, and plenty of it, is such a desideratum in the plains, as well as in the hills of India, and especially at the great military stations, that the attainment of it might, I think, be made an object of experiment, even if costly and at considerable risk of failure. With this in view, it has often occurred to me that these plains, at all events the portions of them within a moderate distance of the hills, are, or at least may be (for the unseen chances are numerous), favourably circumstanced for artesian wells. There is not indeed the basin-shaped arrangement of the strata as in the typical examples of the London and Paris *basins*, but there is something equivalent. The slope of the plains is steady and considerable from the foot of the hills southwards. The arrangement of the strata, according to the best received views upon the plains' deposits, is also favourable; they probably have a gentle slope of deposition, some-

what greater than the slope of the plains, and in the same direction. There are probably coarse and more porous beds overlapped by finer and retentive deposits; a large portion of the water that is known to be absorbed along the gravel deposits, which everywhere occur along the base of the Sivâliks, may be, I think must be, carried down to saturate these lower beds. It is certainly difficult to take account of what complications in stratigraphical arrangements may occur in the Sivâlik rocks below the plains' deposits, or to say how these might affect the scheme we are considering. It is probable that the contortions which affect these rocks so powerfully where we last see them, continue for a considerable distance to the south. They may rise into underground ridges, which would considerably interfere with the regularity of the succeeding deposits, and so dam up the underground circulation. For instance, there might be a steady ridge of this kind a short way to the north of Meerut, nicely capped by stiff clay beds of the overlying series, and thus effectually cutting off the source of supply. It seems likely, however, from the complete disappearance of these rocks beyond a well-defined line, that they are deeply buried beneath the deposits of the plains. As regards the plains' deposits themselves, there are also some important points upon which our information is vague. Even granting the general prevalence of coarser and more porous strata at the base, it may be asserted that the stratification is so irregular, and the interlapping of porous and non-porous beds so complete, as to render impossible the existence of an artesian water basin, and that therefore the actual water level is the highest that can be obtained. I know of but one observation bearing upon this question, and it even is not entirely in favour of either side; it shows, at least, that partial artesian water-basins do exist—water-bearing strata, in which the water has some ascentional power. I have been told by an engineer, that in sinking a well sixty or seventy feet deep (I regret that I have mislaid my memorandum of the exact conditions), after passing through a bed yielding impure water,

and one below it of retentive rock, a lower bed was reached, from which pure water rose freely for some feet. The locality was somewhere between Allighur and Agra.* It may be that from a still lower bed the water might rise higher, or even to the surface,—such facts are common in artesian borings.

The fullest details as regards surface levels may be obtained in Colonel Cautley's great work on the Ganges Canal. I will quote a few figures in illustration of our argument. The upper level of the gravel slopes along the base of the Sivâlik hills, between the Ganges and the Jumna, ranges between 300 and 400 feet above the floor of the regulator at the head of the canal, which may be spoken of generally as the Ganges level at Hurdwar. It may then be laid down that no head of water could arise from those gravel beds standing at a higher level than the canal floor at Myapur; or, to be well within bounds, let us say 100 feet below that level. Meerut

* I have re-discovered my informant, A. G. Murray, Esq., C. E., of the East Indian Railway, and am glad to be able to add the interesting facts he communicates upon the subject of well water in the Doab. I give an abstract of his letter, dated 5th January 1864:—The general section of the Doab is—loam, thirty-five feet; blue silt, thirty feet; strong clay, twenty feet; water-bed of reddish sand. All kutcha wells get their water from the blue silt; it is always more or less saltish, in some places so much so as to prevent agriculture. This blue silt appears to underlie the whole Doab; it is exactly the same stuff as that found in the bed of the Jumna. The pucka wells are sunk down to the clay, and rest upon it. The upper water-stratum is shut off by short piling puddled; the water is then drawn off and a bore-hole, eighteen inches in diameter, is made through the clay, when the water rises very fast and will rest at thirty feet in the well. The clay bed is not horizontal; it slopes from north to south at about two feet per mile, that of the surface being about eighteen inches per mile. At Toondlah the clay is eighty feet from the surface, and forty miles north of Toondlah it is only sixty feet. The Jumna seems to run in a depression of the clay bed, and this may explain why good wells are scarce near the river, people are afraid of the expense. For instance, at Agra as good water is to be had as anywhere else by sinking to the proper depth. Just south of Allyghur the water bed takes a rapid rise, that I cannot explain: at Allyghur it is but fifteen feet from the surface, while nine miles to the south it stands at thirty feet. The supply of water in these pucka wells is apparently unlimited. For six months thousands of these wells are worked all over the country, yet without affecting the supply. I do not see where it can come from except from the hills, and I still believe that an artesian well is quite possible in the Doab; if the Government would make the experiment it might prove a great public benefit.—*Jan.* 15, 1864.

is 200 feet lower than the Ganges at Hurdwar, thus we have still 100 feet to depend upon. The Ganges at Gurmuktesur, the nearest point to Meerut, is 300 feet below the same point; but here, and for long above it, the *Kádur* valley is cut in the upper strata of the plains' deposits, which we have presumed to be retentive in comparison with those below.* Meerut is about seventy miles in a direct line from Hurdwar.

The question might be greatly elucidated by special observation of the many features bearing upon it; but, even supposing the result not to be altogether favourable, the limits of unavoidable doubt are wide enough to sanction a trial. It would be difficult to over-estimate the value of a free supply of good water at the great military stations. At present I consider the chance a fair one, and I would recommend Meerut as a suitable position for the experiment.

I know of but one attempt of this kind in the plains of India, that made about twenty years ago in Fort William, at Calcutta. A boring was sunk to about 500 feet, but without success. Coarse gravel was reached at a depth of little over 100 feet. This of course was an unfavourable circumstance, and one very little to be expected—illustrating how uncertain our prognostications must be. I do not think, however, that this case of failure should deter from a trial in a place where many of the conditions are so different.

* *Kádur* is the local name for the actual river-valley; this is often several miles wide, is annually flooded by the river, and within its limits the deep water channel frequently shifts its position. *Bhangur* is the name given to the land rising immediately from the kádur, generally in a vertical cliff from thirty to fifty feet in height, and rising to more than 100 feet in the centre of the Doab—the area between two rivers. Upon this land the action of the river has long been, and must continue to be, erosive.

APPENDIX.

On theories of mountain formation.

In every country the first object of geological investigation is the chronological co-ordination of the rock-formations. Next to this the question of greatest interest in the region to which the foregoing memoir refers is that of mountain-structure. Had my personal knowledge of the Himalayan rocks been much more extensive than it is, or could I have obtained from other sources a corresponding knowledge of a large portion of the Himalayan region, I might have made an attempt to solve the problem of the general structure of the system. As it is, any such attempt must have been premature. I have done little more than to group some of the data and to point out the bearing of my observation upon existing theories of mountain-structure. The necessary incompleteness of my work must be my excuse for appending to my observations a sketch of what I understand these theories to be. I shall moreover thus fulfil a special object in a treatise intended primarily for India, namely, to afford as much as possible collateral and preliminary information for the assistance of those who may be willing to aid in the extension of a scientific knowledge of the country: for lack of some such suggestions many an intelligent observer has expended his labours almost to no purpose. And even to the general student of geology an abstract of the prevailing opinions upon mountain formation may not be amiss; for, that our knowledge on this important subject is in a very scattered and unsettled state, is clearly enough indicated by the scanty notices which our latest and most approved manuals of geology take of it,—we find high authorities still advocating incompatible explanations,—the mode of origin of the mountain areas that have been most carefully studied is still doubtful. The doubt and obscurity to which I here refer is however readily explained by the consideration that the phenomenon in question is a result of underground agencies, of which the conditions are so difficult of investigation.

Our knowledge of mountain formation very deficient.

Besides the intrinsic difficulty to which I have just alluded, there is another, and an extrinsic impediment to our knowledge of mountain-formation, to which I must briefly allude. It is, the habit that prevails of confounding two very distinct aspects of nature, the actual and the retrospective—the habit of not distinguishing between facts regarded as elements in the existing harmonies of nature, organic and inorganic, and facts regarded as the productions of past activities. The former view is that belonging to physical geography, the latter to physical geology. Both sciences have suffered from the mistake,—physical geography has been thereby encumbered with difficulties that do not belong to it, and physical geology has become infused with a looseness that is most prejudicial to its progress. Observations that may be valuable contributions to the former science may have a very insignificant bearing upon the latter. For example, hypsometrical details (the exact determination of elevations) form

Confusion with physical geography.

a prominent object in simple orography (delineation of contour), yet are of but very subordinate consequence in the discussion of mountain-structure. From one of the many partial points of view in physical geography we find even *elevation* made little of. We find Dr. Hooker in his 'Himalayan Journals', Vol. II., p. 387, speaking of the "true Himalayan axis" as a question of watershed, making "mere elevation of secondary importance." The approximate determination of a line of elevated country is *in itself* of much interest in physical geography, but has little or no independent meaning in physical geology, and if so applied such facts are almost sure to lead to error. It were easy to adduce instances of geological speculations founded upon no other basis than these subordinate facts. The example of Von Humboldt, at a time when geology was in its infancy, has given much encouragement to what must now be considered an unscientific confusion of ideas.

We must then at once draw a clear dictinction between these two essentially different aspects of mountain phenomena. As simple conditions of the earth's surface, affecting the actual life of the planet in the distribution of climates and of living creatures, the *form* and the *position* of mountains are the only features that we need consider; and the appropriate grouping of mountains for this purpose should rest largely on the single fact of continuity. Such is the aspect that belongs to physical geography.

Physical geology assumes a very different point of view. Its object is to investigate the mode of origin of mountains. The facts which may throw light on this question are very numerous and yet obscure, and an appropriate definition of a mountain system in this sense might be—all elevations, whether continuous or not, which are the result of a single act of nature. For example, from considerations of climatology and natural history, as facts of physical geography, the Alps or the Pyrenees form a simple and independent group, having no natural affinity to the Himalayas, or the mountains of Northern Africa; but from the geological point of view, affinities have been asserted between these chains, and may, for aught we can yet say, exist; and further, from the same point of view, several quite distinct systems of upheaval have been supposed to be represented in the single orographical area of the Alps.

It is to be regretted that our best writers on physical geography, still following in the track made by the great founder of the science, Von Humboldt, confound distinct branches of scientific investigation. The result is an incongruity in their productions, *viz.*, a general predominance of a purely geographical arrangement with frequent vague reference to geological systems. What is simple is obscured by them, and a most objectionable looseness is introduced into an investigation that demands the utmost clearness and patience. Even supposing our knowledge of mountain-formation to be complete, the distinction I point out would still obtain. The confusion is the more objectionable when we know it to be based upon a *theory* that is very far from being established, and that is opposed by views leading to diametrically opposite results. We will presently see that this contradictory relation exists between the views of disturbing agencies adopted by such high authorities as De Beaumont on one side, and Babbage and Herschell on the other: the theory of the former aims at universal symmetry, that of the latter legalizes disorder.

General and local causes.

In approaching the question of mountain-structure,—how it is produced—the first question that presents itself is to what extent the causes of geological disturbances are general or local. By general causes are meant, agencies that affect the whole earth, such as the slow refrigeration of the mass, or, tidal phenomena in a fluid internal mass; local causes are such as proceed from the local

development of force, such as the supposed generation of heat by chemical means, or such a natural cause as the removal of materials from one part of the surface to another. The theories I have to notice are more or less dependent upon one or other kind of cause.

Unsymmetrical form of the earth.

The question of mountain-formation seems but a special case of the general problem of the inequalities of the solid surface of the globe. A first glance at these inequalities brings to notice their very unsymmetrical distribution. In connection with this fact Sir John Herschell states in his Physical Geography (p. 15) that the centre of gravity of the earth is slightly excentric to that of the external figure, and in the direction from the hemisphere of greatest elevation; he further points out the necessary inference, that the force which sustains our continents is one of *tumefaction*, such as would be produced by an increased temperature beneath their area. Symmetry being the necessary result of force acting under homogeneous conditions, we have to seek the secondary or partial causes which have resulted in the very unsymmetrical arrangement of the earth's surface as we now find it. In such speculations we are of course limited to known causes; for instance, it would not be admissible in explanation of the earth's unsymmetrical form gratuitously to suppose the presence of a larger volume of some peculiar light substance beneath the area of most extensive elevation. The phenomenon in question is so extensive relatively to the whole mass concerned that any cause which could by one operation produce such a result must be considered general as regards our globe. We know of no such cause. We can conjecture no agency by a single operation of which this unsymmetrical tumefaction of the earth's mass can be produced. We are thus driven back to look upon the tumefaction as cumulative, and upon its cause as local. In this way a case of general elevation seems to be brought back to a special one. Even in those theories which introduce general causes for the production of the special elevation of mountain chains the modifying influence of cumulative local causes has to be recognized. For example, M. de Beaumont in the elaboration of his grand scheme of ultimate symmetry allows that the actual tuberances (*bossellements*) of the surface cannot be the *simple* result of any actual state of tension.*

De Beaumont's theory.

In noting various theories of mountain-formation, I give precedence to that of M. de Beaumont, as detailed in his "*Notice sur les systèmes de montagnes*"; it is beyond comparison the most elaborate in design and execution, and it treats the subject from the point of view of general cosmical action. It was observed that mountain chains are rectilinear, or made up of rectilinear elements. By comparing these chains or elements of chains it was found that they could be arranged in groups, having a common direction, under certain conditions of parallelism. This result formed one premise of M. de Beaumont's theory. The other was found as follows:—By examining the rocks composing, and contiguous to, a mountain chain, the relative date of the disturbance can be approximately ascertained; mountains, and disturbances of every degree,

* I have introduced this paragraph to place some limitation to the phrase so freely and so vaguely used by geologists, and so likely to lead to misconception, namely, the expression *continental elevation*. Very large areas have no doubt undergone changes of level at one and the same time, but the formation of continents is probably the result of very broken and disconnected chains of causation. In the present vague state of our knowledge of the causes of elevation, and of our very limited acquaintance with facts, it is impossible to give an exact meaning to the expression. The sense attached to it by the best authorities is, I think, as opposed to spasmodic, lineal elevation. In its simple orographical application there can be no ambiguity.

can in this way be roughly arranged in groups having a kind of order of date. From these considerations the final induction was made by the comparison of the two series of groups ; there were thus discovered some remarkable cases of apparent coincidence, the same individual chains forming groups in the two categories. This striking fact was enunciated in the theory that parallel mountain chains are of synchronous origin, and *vice versâ*. Such a group of parallel lines of elevation or of disturbance is what M. de Beaumont means by a *system of mountains;* members of the same groups, according to his view, occurring often far apart, and quite unconnected by any visible feature.

The adoption of such views as those just indicated involves that of a world-wide force affecting the whole earth simultaneously, and to the complete subordination of local or superficial influences. The author accepted this necessity in the boldest manner, and framed a theory of action commensurate with its demands. Upon the basis of a very generally received opinion—the great internal heat of the earth—he states the conditions that might fulfil the supposed results. These conditions were, a fluid internal mass covered by a comparatively thin solid crust. The gradual loss of temperature which the total mass would undergo must be almost exclusively at the expense of the highly heated interior, and the consequent contraction would also be confined to the fluid matter in the interior. In order to adapt its capacity to the diminished volume of its contents the spheroidal shell would become distorted, producing tuberances (*bossellements*) of the surface. The tension thus produced would at last result in rupture, and a new equilibrium would be established by the crushing of the shell along the lines of fracture. He adduces mechanical laws to show that these tuberances and lines of fracture would occur within a *fuseau*.*

Not content with giving a complete account of one single convulsion of the earth's crust resulting in the formation of one system of mountains, M. de Beaumont goes on to show, and he illustrates the idea by an appeal to facts, that successive convulsions must so occur that these characteristic directions should group themselves in pentagonal symmetry. For this complete generalization he again appeals to geometrical and mechanical principles. He states that in such a splitting up of the sphere the pentagonal form gives a maximum of result with least effort. Consistent with the postulates on which he starts, our author adopts in their fullest sense the doctrines of the supporters of geological catastrophes.

In reading M. de Beaumont's work it is impossible not to be captivated by the beautiful order he establishes out of an apparent chaos. Even with a full knowledge of how inexact the facts must be upon which he proceeded, and of how erroneous many of his assumptions have been proved to be, one cannot help giving way to an unscientific feeling of hope that in the main he may be right. As the author himself admits (p. 1259), all that is essential in the theory seems to be compatible with other conditions than those adopted by him, such as with a solid sphere and comparatively cool interior, or with a gradual action instead of a sudden catastrophe, the one unalterable feature being permanent surface temperature and reduction of internal heat. Our study of the Himalayas may have added fresh evidence against

* A segment of a sphere contained between two great, conterminous semi-circles of the sphere. He gives (p. 1255) a probable limit of 20° for the width of the fuseau within which the same system of disturbance can occur. The author further insists (p. 674) upon the probable irregularity in direction of fissures occurring near the points of the fuseau, and hence he infers the probable *difference* in age of ranges situated at the antipodes one of the other and parallel to the same great circle of reference, (the circle bisecting the fuseau longitudinally): such ranges probably belong to different overlapping fuseaux.

the non-essential features of De Beaumont's grand scheme, but on the theory itself very little light can be thrown by the examination of so limited an area. He only deals with mountain systems and with the great elements of direction, and time of production as a whole. In fact M. de Beaumont's speculations go so far beyond our actual knowledge of geology, both descriptive and physical, that the full verification of them must be left to future generations.

The character I have just expressed of De Beaumont's theory is borne out by the inattention he shows to the minor facts of the case under examination, to the secondary effects of the general phenomenon, the stratigraphical features of contortion and displacement that must attend these great efforts of nature. At least in his special work on mountain systems there is only an allusion to these features, and that allusion is to disclaim any decided views on the subject ; he states (p. 1344) that his general theory is independent of any special mode of action, such as crushing (*écrasement d'un fuseau*), or sinking, (*affaissement*), or direct elevation, all of which he leaves open to discussion. It may be that, according to circumstances, any one of these modes may dominate, but we must, I think, believe that a proper discussion of the facts of structure will enable us to say what that mode was in any case ; yet it may often also occur that the result is so complicated as to be impossible of explanation. It thus remains evident that direction and the time of production are the only elements essentially involved in M. de Beaumont's theory, and by which he has left it open to verification.*

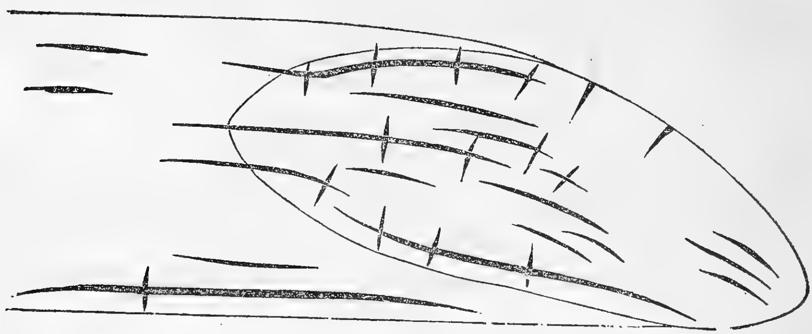
Mr. Hopkins' discussion of elevation.

In the sober views propounded by Mr. Hopkins (Trans. Geol. Soc., 2nd Series, Vol. VII., 1841) we find a salutary check upon the too ambitious theories of M. de Beaumont. Mr. Hopkins limits his discussion to a single area of elevation, his object being to elucidate the proximate mechanical conditions by which such a feature may be produced ; he subsequently submits his theoretical considerations to rigorous comparison with actual example. His views originated, like those of M. de Beaumont, in the perception of symmetry in features of disturbance,—in the long-recognized fact of the approximate parallelism of lines of dislocation in the districts in which systems of such lines are found to exist. The hypotheses he adopts, for the theoretical consideration of the question, respecting the constitution of the mass acted upon, and the action of the elevatory force, are very simple. He assumes the mass to be uniformly cohesive, at the same time indicating the effects of variations in this respect within known limits. For the force, he assumes it to be vertical, to be simultaneous, and to be approximately uniform over the area affected, such, in fact, as would be the result of fluid pressure. With reference to the form of the area affected, Mr. Hopkins lays down two theoretical limits. In a circular area a uniform force would tend to produce concentric fissures ; or, if acting with greater intensity at the centre, it would produce fissures diverging from the centre. In an area of limited breadth but of indefinite length longitudinal fissures alone could be formed, corresponding to the concentric fissures of the circular area. Actual cases will be compounded of these two. It is not necessary that the lines of longitudinal fissure should be continuous, but they must observe a parallelism to the *geometrical axis* of the area. The transverse fissures must be at each point perpendicular to the longitudinal ones.

* Mr. Hopkins in his Presidential address to the Geological Society of London (Quar. Jour., Vol. IX., 1853) gave an elaborate analysis of M. de Beaumont's theory, showing many objections and difficulties in the way of its acceptance, but it seems to me that he fails to give a perfectly correct interpretation of some of De Beaumont's views, such as those regarding the limitation of the fuseau, and again those regarding the mode of production the fuseau and its fissures.

Fig. 18 represents a combination of fissures more or less like what must result from

FIG. 18.



An area of special elevation with its longitudinal and transverse fissures, according to Mr. Hopkins' hypothesis.

conditions such as I have described: the curved boundary shows a partial area of greater elevation, the broad lines which are not continuous represent fissures, longitudinal and transverse.

In the memoir from which this abstract is made Mr. Hopkins describes the area of the Wealden formation in the south-east of England, in which the features of disturbance correspond in a most remarkable manner with the lines in this figure,—hence the legitimate conclusion that their mode of formation corresponded with the assumed conditions, and that these conditions are natural. As an actual cause Mr. Hopkins adopts the supposition of extensive cavities within the solid crust of the earth, in which the expansion of fluid or gaseous matters produces elevations. The phenomenon of faults necessitates (he conceives) the existence of plastic matter below. For the production of such a result as that described in the district of the Weald, Mr. Hopkins considers that one dominant effort of elevation must have occurred by which all the lines were simultaneously struck out ; for the presence of one fracture would interfere with the subsequent production of others. Should subsequent research in any important degree alter the observations made by Mr. Hopkins in the district of the Weald, his paper will retain its value as a discussion of one set of conditions.

Besides the beautiful system of structure exhibited in this example of the Wealden area, the most important inference to be drawn from it is the unity and completeness of the whole phenomenon ; each feature lends itself to that next it ; there is nothing to suggest that this elevation is but a partial product of a world-embracing tension. In connection with this view the form of this area is most important, proving as it does the very considerable deviation from rectilinear parallelism that can obtain among the main fissures of the same area of elevation. This is so marked in the case of the Wealden elevation that M. de Beaumont, in support of his theory, had to deny the principal result of Mr. Hopkins' investigation—the unity of the phenomenon—and to place the different parts of this area in different systems of elevation, formed at different times.

From the point of view taken by Mr. Hopkins, the first object in examining any district is to define the area affected by the same limited system of disturbance, and then the general lines of dislocation,—the fissures which are the primary results of elevation. As for the

secondary results, such as faults, anticlinals, lines of curvature, &c., Mr. Hopkins only states that, as immediate consequences of the fissuring of the crust, they follow laws of distribution corresponding to the fissures. Fig. 19 represents a transverse section of an area of elevation at the instant of rupture, Fig. 20 an imaginary subsequent condition.* However secondary they

FIG. 19.

Diagram cross-section of an area of special elevation, at the moment of fracture.—*(Hopkins.)*

FIG. 20.

Section showing subsequent condition of same area.—*(Hopkins.)*

may be, these features are all important in practice, and it is to be regretted that Mr. Hopkins does not say more about them. But the term fissure is vague, and, as a fact, a simple fissure is rare to meet with, and difficult to detect. Indeed, in the area of elevation described by Mr. Hopkins, the features identified by him as corresponding to the theoretical lines of longitudinal fissure are, almost without exception, lines of fault or of contortion, *i. e.*, something more than mere fissures. In the case of the transverse fissures, this term is more strictly applicable. Some explanation of the phenomena of flexure is especially called for in an identification of *natural* conditions, for those features are rarely if ever absent, and it often seems impossible to account for them upon the sole condition of elevation, and without some influence of lateral force more than is *primâ facie* derivable from the supposition of a simple elevatory force. The inspection of the actual sections of the Wealden district given by Mr. Hopkins will indicate what I mean. I take one as an example (Fig. 21). When from the consideration of such a simple case as the elevation of the Weald,

FIG. 21.

A cross-section of the Wealden area.—*(Hopkins.)*

* These figures are taken from a paper by Mr. Darwin, as quoted from Mr. Hopkins' paper in the Cambridge Phil. Trans., to which work I could not procure access.

we pass to that of a great mountain chain, the want of some guiding principle in the interpretation of complicated contortions becomes greatly felt. It is to men such as De Beaumont, Hopkins, and Haughton that we must look for the fit discussion of this subject. Mr. Hopkins gives very little encouragement to the attempt. In order to study the comparison of actual with theoretical results, he tells us that he chose the area of the Weald " on account of the regularity of its boundary and the apparent absence of the effects of that more violent, local, or irregular action of elevating force, which it must ever be impossible to reduce to calculation" (p. 1).

H.D. Rogers' theory of disturbance.

Professor H. D. Rogers (" Geology of Pennsylvania," 1858) has paid more attention to detail of stratigraphy than did either De Beaumont or Hopkins. His opinions are principally based upon the study of the Appalachian mountains of America ; but, both from observation and from written description, he attempts to affiliate other regions to the same laws of structure. The Appalachians are described as one chain, demonstrably elevated at one epoch. The range is 1,500 miles long by 150 broad, but is divisible longitudinally into eleven sections, five of which have a curved axis, and six are straight ; three of the latter have an approximate north-south direction, and three run nearly east-west or almost at right angles to the others. Mr. Rogers points to these facts as incompatible with M. de Beaumont's theory of parallelism and synchronism. Throughout the Appalachians the strata are waved, the undulations observing a parallelism among themselves, and with the igneous axis of the district in which they occur. In most parts of the chain waves of two magnitudes are to be found ; the larger of these attain great dimensions, being from 50 to 120 miles long, by several miles wide ; the subordinate or secondary waves are seldom more than ten miles long, by half a mile wide. These latter are regarded as only local corrugations of the superficial rocks, not true undulations of the crust. Parallelism does not necessarily obtain between these systems.

In the *from* of waves Mr. Rogers distinguishes three essential types. The first is *symmetrical flexure,* a curve of which both slopes are equal. This variety is generally restricted to the gentler undulations. The second kind is the *normal flexure*. It displays a greater steepness on one side than on the other. This form prevails where the forces of disturbance were neither intense, nor yet feeble ; and it is found to occupy an intermediate position geographically between the two other varieties. As a general rule, in any one region the steeper slopes are all in the same direction. The normal flexure attains its limits when the steeper side becomes vertical. Beyond this limit we have the third class, called *folded flexure,* in which the strata on one side of the axis of the curve have been displaced beyond a vertical position, so as to approach in parallelism to the strata on the other side of the axis. As in the case of normal flexures the more incurved sides of the folded waves in any district generally slope in the same direction.

Regarded longitudinally, each wave has its maximum height in the middle of its length. The form also may change : from being of the folded variety in its middle portion a wave may become normal and symmetrical towards its terminations. Starting, in any group of flexures, from the side of maximum disturbance, which is also invariably the quarter of greatest igneous action, the waves exhibit a similar gradation, and at the same time an expansion in the width of the wave. The generalised section of the Appalachians

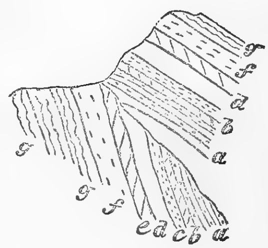
FIG. 22.

General section of the Appalachian Mountains.—(*Rogers.*)

(Fig. 22) given by Mr. Rogers exhibits the facts last mentioned. In the matter of fractures and faults, *i. e.*, in respect of the tension in which these cracks originate, each anticlinal belt may to some extent be looked upon as a distinct area of elevation; each wave has its own system of fissures. In this way Mr. Rogers subordinates the fissures, at least the lateral fissures of a great system, to the flexure; he says, "these great fractures are only flexures of the more compressed type which have given way in the act of bending." In the great majority of instances these fissures coincide neither with the anticlinal nor the synclinal axis planes,* but with the steep or inverted sides of the flexures. He describes such a fault eighty miles long, and having a throw of 8,000 feet. Faults such as are here described generally underlie in the same direction as the axis-plane of the flexure, and it very commonly happens that the upthrow takes place on the side of the underlie, producing, as *normal results*, what are commonly called *reverse faults*.

Fig. 23 represents an anticlinal flexure so faulted. Faults of this kind are, as their name indicates, generally supposed to occur very rarely, and only on a small scale. Mr. Rogers, however, describes them as a common feature in mountain structure. They produce the anomalous appearance of older strata overlying newer. The folded flexure itself produces this effect, but in a less marked manner than when faulted.

FIG. 23.



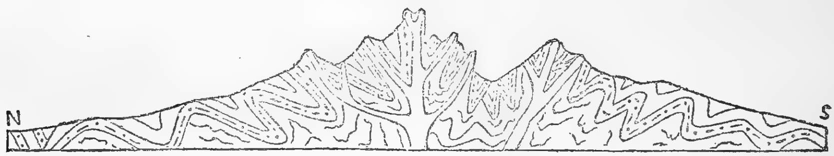
Reverse fault along a folded anticlinal flexure.—(*Rogers.*)

It was only the absence of any ascertained order in the phenomena of contortions that has hitherto excluded them from their due position in speculations upon the nature of the causes of disturbance of the earth's crust. In the comparatively regular structure of the Alleghany mountains, Mr. Rogers conceives that he has discovered this order. He asserts that undulation is the prevailing law of all displaced deposits, and that waves of translation are the archetypes of these undulations. He consequently declares that any theory upon this subject, henceforth admissible into physical geology, must explain the general facts of the regular wave-like structure of the earth's disturbed zones. He points out that no simple upward pressure could have this effect. He affirms that simple lateral pressure could not result in such regularity. He conceives this structure to have originated in a true wave

* The axis-plane of a flexure is a plane bisecting the angle of incurvation.

motion on the surface of the molten matter upon which the earth's crust is supported. In the first instance he supposes the strata of the region affected to have been subjected to excessive tension, arising from the expansion of solid matter and of vapours ; this tension is relieved by linear fissures, and the sudden release of pressure adjacent to these lines of fracture produces violent pulsations on the surface of the liquid below. A tangential force would take advantage of these regular undulations to produce folds and reverse faults such as Mr. Rogers describes. The generalized section of the Alps (Fig. 24), as conceived by Mr. Rogers, exemplifies well this author's views of the flexures of strata,

FIG. 24.



Generalised section of the Alps.—*(Rogers.)*

and their relations to mountain formation. In this figure there are four belts of closely folded waves, each belt having its axis planes dipping towards the centres of their own high mountain system.

In Mr. Rogers' application of his theory to the Appalachian mountains he has omitted to discuss a question of considerable importance. Each of the theories we have examined supposes a zone of maximum intensity of action (geological effect). Indeed it seems to me a necessary condition of every theory of elevation. As a consequence, and with any thing like homogeneous conditions of resistance, we should expect some approach to a bilateral symmetry in the resulting disturbance of the rocks. In the sections of the Wealden and of the Alps we see examples of such a symmetry. The more a theory adopts the supposition of intense internal action and a consequent subordination of superficial influences of resistance, the more does it involve this symmetry. Mr. Rogers' theory is eminently of this nature. But it is his facts and not his theory of which we are to seek an explanation. In his section of the Alleghanies there is a steadily increasing intensity of disturbance in the strata towards the east and south-east border, even to beyond the limits of the chain itself. Both the form and the gradation of intensity of the flexures point to a region external to the chain as the axis of disturbance. The Appalachian chain is therefore wanting in symmetry as a mountain chain, it is essentially one-sided. If we are to accept Mr. Rogers' theory in its full development, we must, I think, to be consistent with it and the facts, look upon the actual Appalachian chain as but a shred of a once far more mighty mountain system, of which the central region of maximum disturbance and elevation stood over what is now the Atlantic slope of the North American continent, the eastern declivities of that chain having been long since removed and depressed beneath the present ocean area. Any one, who had only read Mr. Rogers' reasoning upon the undulation and elevation of strata, would look upon the gneissic and intrusive rocks to the south-east of his Appalachian section as the physical equivalent or analogue of the similar rocks in the middle region of the Alps,—as the result of the great central upheaval, fracture, and protrusion upon which his theory so strongly insists, and of which the undulations of the Appalachian strata are, according to it, but a

secondary effect, and one would expect to find in the region east of the Appalachians, supposing the section visible, a system of disturbance equivalent to that on the west. The only other alternative seems to me to involve a great modification of Mr. Rogers' theory of elevation, and to imply a far greater influence of superficial, modifying causes than he makes any allowance for. Accepting the features of contortion described by him we must still believe the centre of disturbance to be external to the present chain, but we can greatly modify the nature of that disturbance ; we can eliminate the idea of great central upheaval and suppose that zone to have been one of weakness and of fracture, and hence a locus of disturbance. The very great difference of conditions which we can reasonably suppose to have obtained on different sides of this central line of intensity removes the necessity for similar effects of disturbance on these two sides. In this way we are led to reject the supposition of symmetry being the necessary type within regions of disturbance, so distinctly implied in Mr. Rogers' statement of his theory. Mr. Rogers makes no allusion to the difficulty I have just attempted to explain as involved in his theory, but by the facts adduced in the descriptive part of his work he leaves little doubt as to the relation of the Appalachian rocks to those of the region to the south-east. We are led to believe that those gneissic rocks were in about their present position from the earliest ages. From the first of the Primal strata to the topmost bed of the coal-bearing group the area of deposition of the great Palæozoic series is represented to have been restricted pretty much as we now find it : and much of the material of these deposits is represented to be derived from gneissic rocks in the approximate position of those now existing.

The grand result of Mr. Rogers' labours, the suggestion of a systematic arrangement in the contortions of strata, as a statement of observation, remains unaffected by the modifications we are compelled to put upon his theory. If his views prove to be generally applicable, they will be of incalculable service in the interpretation of geological sections.

MM. Babbage and Herschell.

Neither Mr. Hopkins nor Mr. Rogers offers any conjectures upon the prime cause of the expansive forces to which they appeal as agents of disturbance. The omission of such speculations cannot be said to detract from the value of their researches ; the independent analysis of facts is the first and the safest method of discovery, yet, as the knowledge of natural causes is the ultimate aim of scientific investigation, our interest in a theory must be influenced by the light it can throw upon these prime sources of activity. This is the secret of the fascination we find in M. de Beaumont's work. For the same reason there is even a greater fascination in a theory which I have now to notice. It is that proposed both by Mr. Babbage and Sir J. Herschell from *à priori* considerations of the general condition of the earth, and it was suggested to these philosophers by the want of a prime mover in the explanations usually given of the phenomena of disturbance. We know from observation that the temperature of the ground is distributed with reference to the form of the surface, and that underground isothermal surfaces correspond locally in contour with that of the external surface. The laws of conduction and radiation of heat show us that it must be so. If therefore the form of the surface were to be altered, if any elevated mass of land were to be lowered, or if any depression were to be filled up, the law just stated would after a time prevail over the area thus altered. If we consider the consequences entailed by this change it will be seen what great results may be produced.

The new surface of the area that had been denuded will no longer have the same temperature as when it was covered by a considerable thickness of rock, and the underground isothermal surfaces, down to the focus of heat will be similarly affected ; the whole mass will have undergone a reduction of temperature proportional to the depth to which the original surface had been cut down, and will have undergone a corresponding contraction of volume. A similar process will come into operation, but in the opposite direction, in the case of the area upon which additional matter had been laid down. What was before an exposed surface becomes an underground surface, and, in the newly established distribution of heat, its temperature will be raised in proportion to the depth to which it has been covered.

If the reasoning indicated in the foregoing paragraph be applied to the familiar facts of geology, we get a natural cause almost unlimited in mechanical power. The thickness of successive deposits is known to be very great, and a deposit in one place involves the removal of the same matter from some other area, generally contiguous. In addition to the influence of these fluctuations of heat in producing depressions and elevations of areas, respectively of denudation and of deposition, Herschell in *his* development of the subject, lays great stress upon the effects of the changes of pressure produced by the same process. Whatever we believe the constitution of the earth's crust to be, we must grant some influence to changes of pressure ; the action would be more immediate than that of the changing temperature, and in the opposite direction, tending to depress areas of deposition, and both directly and by re-action, to elevate areas of denudation. By the legitimate application of these two prominent elements of the theory—depression by weight, and expansion by heat—it is possible to give a satisfactory, or at least a plausible explanation of most phenomena of disturbance. One of the most important inferences of this theory, bearing upon the formation of mountains, is the indication it gives of a position of weakness and of strain between the area of deposition and that of denudation, culminating in fracture, shock, and possibly intrusion or ejection of igneous matter.

Judged upon *à priori* grounds alone this theory is even more complete than that of M. de Beaumont ; both start from this simple fact of a high internal temperature, and the necessary process of slow refrigeration. M. de Beaumont makes this process, and all the results which it entails, self-regulating ; whereas Babbage and Herschell propose to maintain the equilibrium by the aid of an equally constant fact—the shifting of materials at the earth's surface, of which phenomenon M. de Beaumont takes no account. The whole earth is sensitive, as one organism, to any modification of its conditions of temperature. There must be an initial tendency to the production of the world-wide tensions of the crust to which M. de Beaumont attributes the production of mountains ; it is also evident that such tensions may be guided and ultimately satisfied by the process to which the other theory appeals.

Mr. J Hall.

The only instance I am acquainted with in which the theory sketched in the preceding paragraphs is applied to explain contortion and elevation of strata is in Mr. J. Hall's account of the Alleghanies or Appalachians, published in the introduction to Part IV., Vol. 3 of Natural History of New York (1859). The author commences with a review of the distribution of the great palæozoic series in eastern North America. He shows an aggregate thickness of these formations in

the region of the Alleghanies, amounting to no less than 40,000 feet, while in the country to the west, where the same series is comparatively undisturbed, the total thickness is not more than 4,000 feet. He gives reasons for supposing that this enormous accumulation of deposits was mainly derived from sources which lay to the eastward and northward. The region of greatest deposition has been also that of chief disturbance. This last fact, which may be only a coincidence, is accepted by Mr. Hall, without discussion, as affording a final explanation; he says, "The line of the greatest accumulation is the line of the mountain chain; in other words, the great Appalachian barrier is due to original deposition of materials and not to any subsequent action or influence, breaking up and dislocating the strata of which it is composed." The existence of ripplemark, of marine plants, &c., shows that the deposition throughout the series took place in moderate depth; continuance of accumulation produced continued subsidence; this prolonged subsidence resulted in the production of a great synclinal depression which is still a feature of the Appalachian structure. During depression the bottom strata suffered distension and fracture, and the upper underwent compression and folding. Mr. Hall attributes the entire elevation of the Appalachian range to this indirect agency, namely, the bulging of the upper crust produced by the plication during general subsidence. In this he seems somewhat inconsistent with the general theory he adopts—that of Babbage and Herschell. He seems to admit no direct local elevation of the rocks composing the Appalachian chain. But such local elevations form a prominent and a necessary feature of the general theory, and an ultimate rising by the general increase of temperature of the earth's crust beneath an area of deposition is as certain, or more so, than is the prior depression of that area, owing to continued accumulation of rock-matter. Mr. Hall appeals vaguely to continental elevation without any allusion to the cause of a phenomenon so opposed to the general tenor of his views. In alluding to the great allied question of metamorphism he is equally vague and inconsistent. He says,—"We must therefore look to some other agency than heat for the production of the phenomena witnessed, and it seems that the prime cause must have existed within the material itself, and that the entire change is due to motion, or fermentation and pressure aided by a moderate increase of temperature, producing chemical change." In extending his views of superficial agencies, Mr. Hall states it as his opinion that overflows of trappean matter are always coincident with the rapid accumulation of sedimentary materials. Without special allusion to the structure of other mountain areas, Mr. Hall asserts the universality of these principles of formation for all mountains, and he attempts to establish a relation, founded on this principle, between the height of a chain and the range of geological formations, involved in its production, and exhibited in its structure. For example, he says, "if the fundamental rocks of the Alps are of palæozoic age, and the sequence has been continued, even with some interruptions, to the end of the Jurassic period or later, it is no wonder that there are high summits, for the accumulation must have been enormous, and if to the Liassic and Jurassic we add the Cretaceous and Tertiary, we may get mountains of the elevation of the Himalaya."

Regarding that most interesting question of the form of the plications of the strata in the Alleghanies, Mr. Hall leaves us in great doubt. He gives no sections in the work from which I quote, but he seems to adopt the facts as stated by Mr. Rogers, simply asserting that his theory of subsidence gives a sufficient explanation of those facts. As I understand the case,

this is evidently not correct. Mr. Hall explains the plication of the strata as the result of the synclinal subsidence of the whole area, causing a crumpling of the beds in the upper portion of the mass. Such a mode of production would necessarily entail a line of maximum depression *within* the area of subsidence, and from which the plications would take their origin in a manner approximately symmetrical on either side. The facts, as given by Mr Rogers, seem quite independent of any such area of subsidence.

In the theory we have last considered, and, indeed, in every discussion involving depression or subsidence of strata, there is a very important element which is commonly lost sight of, namely, the earth's curvature. We are very naturally accustomed to look upon the bottoms of seas, and, in general, any area of deposition as hollows, or actual concavities of the surface. Mr. Hall, for instance, speaks of the lower strata of the Appalachian area during depression as subjected to tension, resulting in fissures, and the consequent intrusion of igneous rock. A more correct representation of the conditions would have greatly strengthened the main conclusion for which he argues. In point of fact, the depression would have probably involved the corrugation of the whole thickness of the deposit and thereby magnified the bulging by which he considers the chain to have been produced. The following table, taken from De Beaumont's work already quoted (p. 1260), exemplifies this fact :—

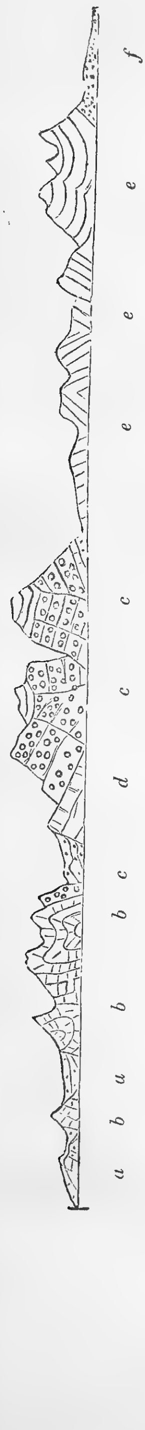
	Distance (arc).	Maximum depth.	Height of surface above chord.	Height of bed above chord.
	Kilom.	Met.	Met.	Met.
The Channel, from Dieppe to Hastings	111	59	242	183
Lake Superior, from Kurewaye Point to Michipicoton	159	241	500	259
Caspian Sea, from Nizabad to Coast of Asia	246	200	1123	923
Baltic, from Memel to Oland	290	100	1651	1551
North Sea, from Whitby to Jutland ...	600	100	6900	6800
Mediterranean, from Toulon to Philippeville	733	2600	10534	7934

From this it appears that the Mediterranean, supposing for illustration's sake, that the deepest point is about the centre, might be filled up with a deposit to a depth of 7,000

feet, and that this deposit might subside through 24,000 feet, and the bottom beds be still subject to compression. Supposing accumulation to have kept pace with the subsidence the resulting thickness would about correspond with that of the Alleghany formations.

S. W.

Fig. 25.



N. E.

Generalized section of the Rocky mountains.—(*Dr. Hector.*)

a, Mesozoic strata ; *b*, Carboniferous ; *c*, Devonian ; *d*, Silurian ; *e*, Schists ; *f*, Granite.

Dr. Hector on the rocky mountains.

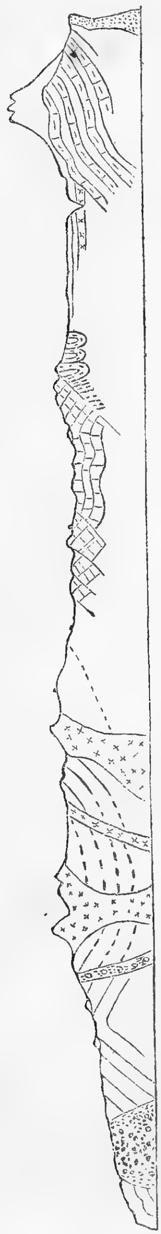
I will add a few examples of less known mountain ranges. In the section given by Dr. Hector (Quar. Jour. Geol. Soc., Lond., Vol. XVII., 1861,) of the Rocky Mountains east of British Columbia, and from which Fig. 25 is taken, we find some exceptional features of structure. The central and highest region is also, relatively to the north-east flanks, a region of upheaval, the lowest rocks appearing there at a greater elevation. Moreover, relatively to this central mass, we find well exhibited in the rocks of the flanking ridges on the north-east repeated folded flexures, of which, as in other instances given, the axis-planes underlie towards the centre of the chain. The central mass itself is, however, neither comparatively nor absolutely a region of contortion, fracture, or intrusion ; the strata are but little disturbed, and have a flat synclinal arrangement. On the south-western flanks we find the lowest rocks of all ; they are much folded, but in no definite order, and at the base in the same direction granite appears. This section has several points of analogy with that of the Alleghanies, the peculiar feature of the central region being the chief discrepancy. The author does not enter upon the discussion of the order of formation of the features he describes.

D. Forbes on the Andes of Peru.

The latest geological description of the Andes with which I am acquainted is that of Mr. D. Forbes, 'on the Andes of Peru,' (Quar. Jour. Geol. Soc., Lond., Vol. XVII., 1861) ; it is given as an emendation of that of D'Orbigny and Pissis. In the section of the Andes, as given by

Mr. Forbes (Fig. 26), we have a form of mountain structure different from the foregoing examples. The section is indeed truncated, the eastern flanks of the chain not having been explored, yet even this incomplete view seems to suggest a very complicated origin for the whole. The eastern and most lofty range is formed of the older sedimentary formations with granitic rocks, while to the west of it, and connected with it by lofty plateaux, there rises an apparently independent mountain range, in which volcanic phenomena are enormously developed.

Fig. 26.



Generalized section of the Andes of Peru.—(*D. Forbes.*)

a, Diorite ; *b*, Volcanic ; *c*, Oolitic ; *d*, Permian or Trias ; *e*, Devonian ; *f*, Silurian ; *g*, Granite.

Darwin on the Andes of Chili.

From his observations of the Andes in Chili, and from his study of the volcanic phenomena in the same regions, Mr. Darwin has made some very instructive remarks upon the phenomena of elevation and of mountain formation (Trans. Geol. Soc., Lond., 1838, Second Series, Vol. VI.) He first establishes the fact of a coincidence, and hence infers a common cause for earthquakes, volcanic eruptions, and the permanent elevation of large areas (continental elevation). He even asserts that no theory of the cause of volcanoes which is not applicable to such elevations can be considered as well-grounded. From the proved recurrence of these phenomena, resulting in an upheaval of several hundred feet within the recent geologic period, he asserts the adequacy of the cause to produce, and explain continental elevation. Observation thus leads him to the same conclusion as Mr. Hopkins, that the fracture of strata and the formation of mountain chains are only subsidiary phenomena attendant on continental elevation. Mr. Darwin makes some very reasonable suppositions to remove Mr. Hopkins' objections to the *successive* formation of parallel fissures ; the process is such a slow one that a long-established fissure might well become clogged up by solidified intruded rock ; and thus lead to the production of a new line of fracture. He believes that such successive formation can be proved in the case of the several axes of the Andes, of which he distinguishes eight or more. He states his opinion that a chain of which the axis is volcanic only differs from one in which the axis is formed of plutonic

(granitic) rocks, because in the former case a complete rupture to the surface took place in the incipient stage of mountain formation, while in the latter, which he calls one of *subterranean* volcanic action, the successive elevatory impulses were satisfied by intrusions below the surface.

In speculating upon the actual conditions of these phenomena Mr. Darwin gives strong evidence,—such as the co-instantaneous ejection of lava from distant orifices, and the rapid elevation of extensive areas,—for the supposition that the interior of the earth is in a molten condition. But he rejects as inadequate any hypothesis that has been formed of the prime mover in these operations, concluding " that the configuration of the fluid surface of the earth's nucleus is subject to some change, its cause completely unknown, its action slow and intermittent, but irresistible.

Great dissimilarity of structure.

The great dissimilarity of structure exhibited in the foregoing examples of mountains, even making liberal allowance for incorrect observations, will suffice to show how comprehensive a complete theory of mountain formation must be, and how very various the primary and secondary causes must be to produce results so unlike. It is obvious that in many cases it may be necessary to look beyond the actual mountain tract to obtain complete evidence of the original phenomena of disturbance. In commenting on the Appalachian section I gave an illustration of this : I showed the possibility of those mountains being but a remnant of a greater range long since obliterated. Mr. Rogers' sections suggest such an idea. Mr. Hall, however, makes these mountains independent, and, as it were, self-created.

True mountains.

The dissimilarity in the structure of mountain ranges might have been made much more striking. We have been taking a somewhat one-sided view only, attending to such cases as are the result of the fracture and contortion of strata, but there are very large and considerably elevated areas, constantly spoken of as mountain ranges, to which we must attach a different interest to that given to what some geologists call *true* mountains, such as those we have been considering. There are, for instance, the Western Ghâts of Hindustan, more lofty and precipitous than the Alleghanies, but they are for the most part made up of undisturbed strata, and offer little or no illustration of the special question under discussion. The difference between the so called true and other mountains is only one of degree. The object of interest is more or less common to all, namely, the internal condition of the earth and the manner in which it affects the crust ; thus every elevated area may be said to involve the supposition of a crust movement, and may in some manner be a record of it, but it is only through the fissuring and disturbance of strata that we can obtain any satisfactory information as to the amount and direction of these crust movements, and hence the special importance of true mountains. It is the necessary tendency of every elevatory action to produce fissuring, and to result in distortion, but under certain conditions, such as those conceived by M. de Beaumont, in which the whole earth is supposed to take part, or even by a less general cause, very extensive elevation may occur without any such result. All fissuring and tilting of strata belong to the same special branch of study as true mountains, which study has for its object the fixation of the extent, amount, form, and duration of the disturbances of the earth's crust.

If we endeavour to extract the elements of observation from the foregoing theories, it is disappointing how little we obtain. The word *fissure* represents a large proportion of the data.

But a simple fissure gives us a minimum of information. Mr. Hopkins tells us that his whole system of fissures would result equally well from a deficiency as from an excess of sustaining force, from depression as well as from elevation. M. de Beaumont also says for his fissures that their immediate cause may be of several kinds, although the general cause from which they are derived is uniform. Thus it would be altogether begging the question to interpret fissures as evidence of elevation. What then are the geological (structural) evidences of special elevation ? The difficulty seems to increase when we come to consider the phenomena of disturbance and contortion. It seems of *primâ facie* evidence that a simple elevatory force, a force acting more or less vertically upward, can only produce tension of strata at or near the surface ; unless indeed it be an expansive force within the crust itself, in which case it will of course exercise a direct compressing action upon strata at a distance, yet such a force would all the more readily find relief in vertical elevation. It may then perhaps be assumed that the tangential forces, by which contortion of strata is effected, must in almost every case be components of gravitation diverted through the arch of the earth's crust. We still have the simpler cases of disturbance to consider. Here the *à priori* answer seems inevitable, that a simple elevatory force would produce some form of regular anticlinal—a tilting of the strata along a line of maximum effort. Mr. Hopkins recognizes this necessity, and both in his theoretical diagram and in his section of the Wealden area he represents an effect of this kind. This question has received much attention under the partial form of *craters of elevation.* It was then mainly discussed on the ground of evidence, and the general verdict of opinion was against the existence of such phenomena. The same decision may, I think, be arrived at against the greater case of *axes* of elevation—lines of upheaval from which the strata are tilted on either side. The Himalaya, as far as we have seen of them, give no support whatever to this mode of upheaval. It is much to be regretted that so eminent an authority as Mr. Hopkins, in putting forward this theory of action as one exemplified in nature, did not suggest some explanation of the general absence of this simple, and initially necessary effect, the only one from which we could draw an inference in favour of this mode of upheaval. The instance of the Weald is an insufficient basis for so important a conclusion.

Thus it would seem that it is rather taken for granted, than proved, that true mountains, elevated areas of special disturbance, are also areas of special elevation. The coincidence is not so striking when we reflect that there are extensive areas of great elevation which are in no degree areas of disturbance, and also, there are extensive areas of great and special disturbance which are (at least at present) but little elevated. Of the former I have already given the Western Ghâts as an example ; of the latter there is a good instance in the granitoid, schistose, and slaty rocks of South Behar, which only here and there form hills of inconsiderable elevation. We cannot however get over the fact that regions of greatest elevation are true mountains, and we must believe that the study of their structure will reveal the secret of their formation. Mr. Rogers' classification of flexures forms an important contribution to this study. The instances I have described of normal and of folded flexures in the Sivâlik strata must, I think, set at rest Mr. Rogers' difficulty as to the formation of such flexures without great crust undulations. It is to be hoped that mathematical physicists will not treat this all important subject with the disregard of which we have had to complain in the theories of M. de Beaumont and Mr. Hopkins, but will come to the

aid of observers with the discussion of some simple hypothetical conditions of contorting action.

Denudation.

There is an important agent in the formation of the earth's orography, which has not yet been mentioned, but of which it is most important to indicate the action to the general observer. *Denudation* is a directly antagonistic power to elevatory forces, its ultimate action tending to remove all inequalities of surface, but in doing so its immediate result is the production of the most intricate irregularities. A study of the existing state of any portion of the earth's surface will show that denudation is in fact more a hill-maker than a hill-destroyer; by far the greater number of what we call hills are its immediate production. In what I say here, I, of course, allude to sub-aerial, pluvial denudation, by rain and rivers. Oceanic denudation may perform a greater amount of work in abrading and transporting matter; it may remove many a thick covering from a slowly rising area; it may cut out coast-lines, more or less indented, which subsequently become inland hills; it, no doubt, too, leaves shallow lines of hollow by which subsequent drainage lines are initially determined; but, as a rule, and as compared with pluvial denudation, it is purely a levelling agent; it carries away wholesale where the other agency would work out mountain systems on its own principles.

Its results compared with those of elevation.

The normal results, such as would be produced under homogeneous conditions, of these two agencies of hill-formation are very different. The tendency of subterranean forces is to produce lines or zones of elevation, more or less longitudinal or concentric. The result of pluvial action upon a level homogeneous mass would be to produce a symmetrical system of hills having a central longitudinal axis with regular primary offshoots, and from these again minor spurs. In this mode of formation the secondary or minor resultant ridges are as characteristically *transverse* as in the other they are *longitudinal*. It has indeed been advanced as a canon in geological dynamics that *all drainage is originally transverse;* the longitudinal valleys being completed by the gradual encroachment upon each other, and the ultimate union, of what were at first but longitudinal (with reference to the mountain axis) feeders of the primary transverse streams: each primary stream so absorbed becomes an affluent of the united longitudinal feeders which have now become the main line of drainage. Thus the degree in which either form is stamped upon any system of ridges, or on parts of that system, may serve as an indication of the influence that either agency has exerted in modelling the actual orography.

Importance of distinguishing the two.

In all discussions upon mountain ranges and their directions, in every attempt to define ridges and lines of elevation as an element of terrestrial physics, it is only in so far as these ranges or ridges belong to the first (the subterranean) order of phenomena that any interest attaches to them. On any other ground there would be really little or nothing of primary interest to discuss, beyond the mere topographical or physico-geographical feature. It becomes then of essential importance to distinguish the effects of these two agencies; it is utterly confounding the subject to set down as a ridge or a system of ridges, and without special mention, a mere series of contiguous elevations forming an irregular watershed, and such as, it is easy to understand, must result under certain conditions from pluvial action alone. For example, unless geologists are forewarned that their ideas are not taken into

account, it is altogether unwarrantable to speak of the "Kasaoli ridge as a branch of the great Himalayan range," which range is described as "bending round to terminate in the plains at Nahun." Or again, to apply the same term to the Himalayan *range*, and the Simla *range*, when by the latter is meant the exceedingly tortuous watershed from Kasaoli to the snowy peaks of Kunawur, right across the strike of the whole series of Himalayan and Sub-Himalayan series of rocks, is also unwarrantable, the intrinsic significance of the two being as different as it could well be.*

Modifying influences.

I have still to notice the influences by which the uniform action of the two active agents of hill-formation are modified. In any actual case the mass acted on will be very far from homogeneous, or even symmetrically heterogeneous. Any considerable area and thickness of the earth's crust is sure to present rocks in many different conditions of induration, and presenting various degrees of resistance. We know too that different systems of disturbance have, at different times, affected the same area, so that the ultimate position of any rocks that have undergone a number of such vicissitudes, will be the resultant of all these separate movements. It is certain that the minor phenomena of any great operation of elevation must be largely modified by these passive influences. In the results of denuding forces, however, these influences become of still greater, indeed of chief, importance. A hard band of rock, into whatever position it may have been pushed by repeated elevation and crushing, will inevitably weather into a ridge. It is easy to conceive these conditions so accumulated that in any great system of elevation large areas, not immediately contiguous to the lines of maximum effect, may show but little regularity in the arrangement of the rock masses. In such a case the heterogeneousness of texture and of structure may be so exaggerated that it practically becomes on a large scale homogeneous again, and the drainage system, resulting from the denudation of such a mass, assimilates more to the transverse or denudation type of origin than to the elevatory, in which longitudinal lines are well marked.

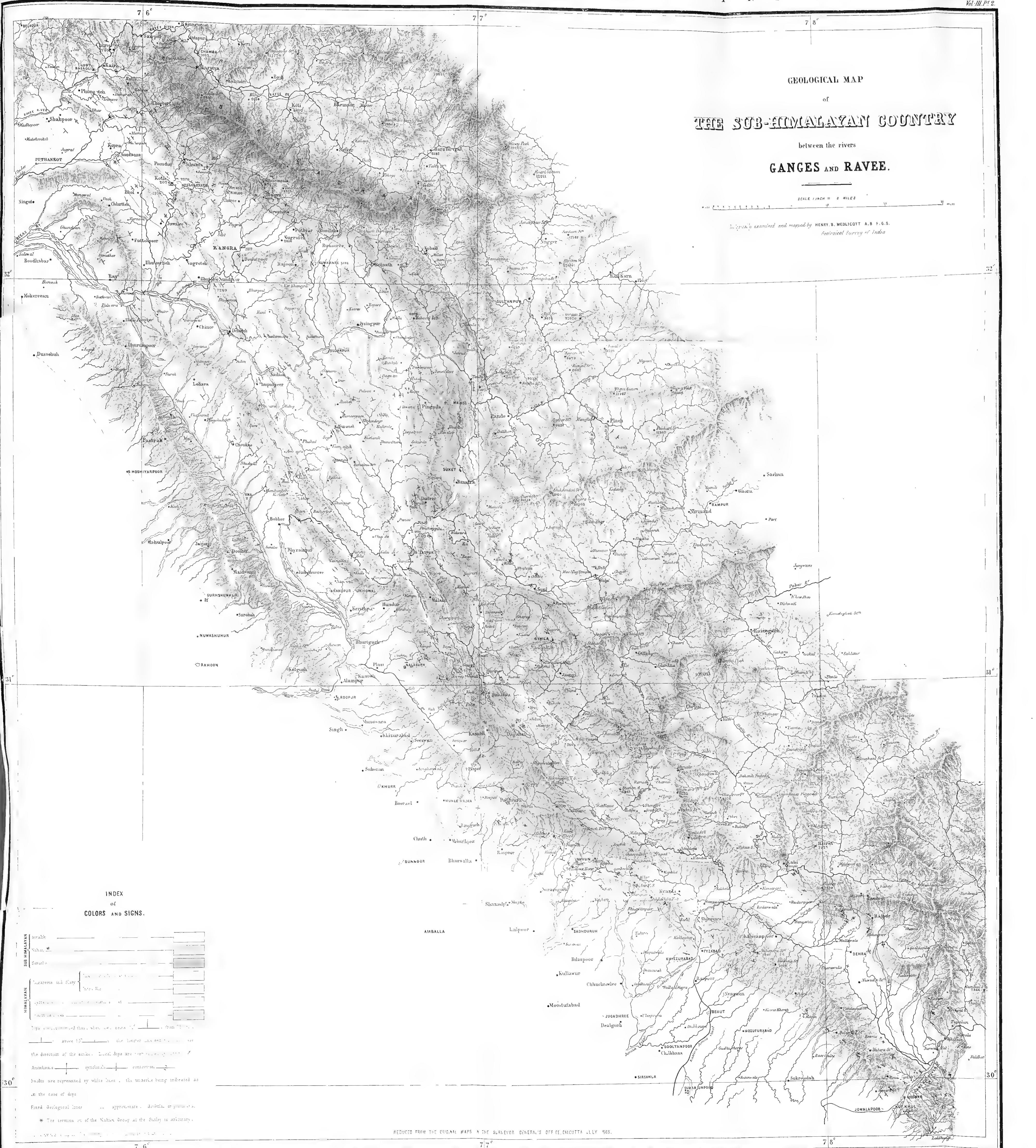
* The errors of the map-maker are even more important to the geologist than those of the tourist, for with the work of the former he cannot dispense. I have often endeavoured to impress upon surveyors the importance of their knowing something of the structure of what they attempt to represent. The reply that one can do no more than copy correctly, or one cannot know everything, can scarcely be accepted as satisfactory. Under the impossiblity of making one anything like a perfect machine, the only safe plan is to make him less a machine. We all know in what a loose sense the word *copying* must be applied to much of the process of the best map-making; but, surely, knowledge would be a safer guide than preconceived ideas in this the artistic element, which is supplementary to the purely mechanical part of the surveyor's work. The little errors that are occasionally found in the admirable map with which I worked in the north-western Himalaya are such as could not have occurred, had the surveyor possessed even a general knowledge of mountain formation from the observations that he could not then have failed to make in the prosecution of his work.

Calcutta, January, 1864.

CONTENTS.

U R

Vol: III. Pt. 2.



LITH BY H.M. SMITH, SURV. GENL'S OFFICE, CALCUTTA, JANUARY, 1864.

Note relating to Sivalik Fauna.—*By* H. B. MEDLICOTT.

(Read to Asiatic Society of Bengal, September 7, 1864.)

The notice I have to bring before the Society may be considered a continuation of a series of brief but important communications, commenced more than thirty years ago, and continued during some twenty years, as recorded in the volumes of the Journal of the Asiatic Society for that period. Those communications formed a current chronicle of the discovery of the *Fauna Sivalensis.* Had the account of those discoveries ever assumed a more connected and complete form, the correction I have now to make, would never have been needed, as it is but the statement of a fact, of which the evidence was in hand and in mind, although never expressed. Indeed, for the same reason, this fact can now be only indicated, its value being still unknown. This fact is—the existence of two vertebrate faunæ, possibly quite distinct, among the fossils hitherto collected from the so-called Sivalik rocks.

In a recently published number of the 'Memoirs of the Geological Survey of India', Vol. III. Part 2, I have given a somewhat detailed account of the geology of the Sub-Himalayan region in North-West India. I therein established a threefold division of the great series of deposits coming under the general title of Sub-Himalayan. Concerning the lowest of these groups (Subathu, etc.) little or no conflicting evidence presented itself. The two upper groups I described as in all respects more akin to each other, although still most clearly separable along a well marked boundary, at which the younger strata overlap the steeply denuded edges of the older, besides being largely made up of their debris. Such evidence is so immutable to the geologist, and, when on so grand a scale, entails such grave considerations of time, that I presumed to call in question the one published statement (in Vol. III. p. 527 of the J. A. S. B. for 1834) of vertebrate Sivalik fossils having been found within the area of the older groups,

not having myself succeeded in re-discovering fossils at the locality indicated. My scepticism was of course based upon the *a priori* consideration of geological time; and because, as I state at p. 105 of my Memoir, no corresponding distinction has as yet been suspected by the authors of the *Fauna Sivalensis*. I made due attempts to authenticate the observation which I had called in question by referring to the original discoverers; as, however, in every reply I received, there was some trace of ambiguity, not wishing to give further trouble to my correspondents, I published the whole case in its unsettled form, giving full directions for the application of the verdict on either side (see pp. 15, 16, 104—6, of my Memoir). I have now the pleasure to announce this verdict, and, notwithstanding the precaution I took to provide for its application, the fact cannot well be stated without a few words of explanation.

In a letter dated the 16th July 1864, Sir Proby Cautley tells me that he has himself collected fossils on the north side of Nahun, *i. e.*, in the rocks of my middle group, the same in every respect as those he had found more abundantly at the south base of the Sivalik hills, east of the Jumna. The peculiar mode of occurrence of these fossils in the nodular clays ('clay-conglomerate' of Cautley), as compared with those found in the coarse gravel deposits, could not escape observation. The former were all small and fragmentary. Large masses of the clay had to be carted from the hills and broken up at leisure in search of the fossil remains. I need scarcely, however, state that the Sivalik fossils have hitherto been given and received as one undivided fauna. Every one interested in these subjects will join in the regret expressed by Sir Proby Cautley that it is now impossible to work the question out, unless upon fresh materials. He informs me that the large collection of these smaller fossils, sent by him with the others to the British Museum, is now not to be found.

To palæontologists then, we may now announce that a most interesting case awaits their investigation, namely, the comparison of well represented vertebrate faunæ, occurring in a series of beds, closely related in point of geological conditions of deposit, etc., and yet distinctly separated (broken) in time.

The application of the fact to stratigraphical geology may now take shape. The strata at the base of the sections visible in parts of the Sivalik hills are representatives of the Nahun group—the middle group of the Sub-Himalayan series. The expression of this on a map must still be arbitrary: for the true Sivalik strata (though so strongly unconformable with the 'Nahun' strata along their junction with the inner zone of these Nahun rocks,) appear to pass conformably and even by gradation into the representatives of the Nahun strata in the outer zone. It is of course to be expected that a very close study will reveal traces of this unconformability in the sections of the Sivalik hills also; but in such massive, banked strata, from twenty to two hundred feet thick, the determination of such a feature will be very dubious.

In physical geology this feature will be only another example, on a larger scale than those given in my Memoir, of the supposition I have offered in explanation of the mode of disturbance of all these Sub-Himalayan rocks—slow contortion and upheaval along narrow zones, synchronously with more or less uninterrupted deposition in the adjoining exterior area.